INSECT COMMUNITIES OF LUCERNE *MEDICAGO SATIVA* L.

IN THE AUSTRALIAN CAPITAL TERRITORY

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To Ruth and Andrew

What follows is all my own work, unless specifically stated otherwise.

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David N. Crawford.

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SUMMARY

Studies were made of two irrigated and two dryland lucerne crop sites in the Australian Capital Territory from 1979 to 1982. Growth patterns of three lucerne cultivars Hunter River, Condura 73 and CUF 101 were assessed by measurements of stem length, distribution of leaves, shoots and side branches. Insect samples were taken using two sweeping techniques and various stem sampling methods, including inspection of plants *in situ*. Analyses were made using indices of diversity, richness, total numbers and similarity. After an initial survey rarities were excluded from most of the analyses. Winged and apterous insect entities were used in preference to species as the basis for analyses. The seasonal fluctuations of phytophagous and predatory insects are described and the incidence of Blue-green aphid *Acyrthosiphon kondoi*, Spotted alfalfa aphid *Therioaphis trifolii* f. *maculata* and Plague thrips *Thrips imaginis* is discussed in detail. Seasonal fluctuations of total insects showed peaks in numbers in spring and autumn but this was largely due to the effects of lucerne aphids and Plague thrips. When these were removed, the remainder (the NLAT insects) showed a peak in summer which coincided with a seasonal low in the ratio of phytophagous/predatory parasitic insects. When the seasonal totals of NLAT insects at Ginninderra Experimental Station were converted into percentage similarity values, it was found that seasonal influences overrode any effects of lucerne variety.

In dryland lucerne pasture there are two components in the insect community, one associated with grassland habitat the other with lucerne. The numbers of this second component of the insect community fluctuate

with the state of the lucerne. Cutting of the crop causes a sharp reduction of insect numbers but the decrease is disproportional, being greatest in some phytophagous species. Grazing by cattle produced a similar decrease in insect numbers, although without the selective effects. Periodic removal of the vegetation and irrigation encourages the plants to produce foliage which seems more attractive to insects than dryland lucerne. If the crop is left uncut the habitat will deteriorate for most insect species due to the loss of leaves and poor regrowth from the basal crowns. Experimental cutting of small plots in tall lucerne showed that recolonization of the cut area was much more rapid than when the entire crop was cut. Removal of weeds from small plots in irrigated lucerne had no significant impact on the insect community.

The results of this study are discussed in the light of theories on invertebrate communities. It is concluded that much more needs to be known about the insect communities of lucerne before comprehensive theories can be developed and put to practical use.

1 - GENERAL INTRODUCTION

Lucerne or alfalfa *Medicago sativa* L. is endemic to the Near East and Central Asia and has been cultivated long before recorded history (Bolten *et al.* 1972). In Australia, lucerne is often grown over southern areas as an irrigated fodder crop and an improver of dry land pasture. Until fairly recently only the 'Hunter River' cultivar which was developed from seed imported with the first European settlement was grown extensively in Australia (Bolton 1962). The lucerne has been subject to spasmodic and localized insect attacks (Whittet 1964, Jarvis and Smith 1946), by native Australian species such as cut worm *Agrotus* spp. (Noctuidae : Lepidoptera) and Plague thrips *Thrips imaginis* (Thysanoptera) (Davidson and Andrewartha 1948 Anon. 1972) that have been able to take advantage of the habitat. Exotic species such as Lucerne flea *Sminthurus viridus* (Sminthuridae: Collembola) and Sitona weevil *Sitona humeralis* (Curculionidae: Coleoptera) have arrived in Australia after the introduction of lucerne also cause problems (Anon. 1967, Clausen 1978, Goodyer and Walters 1980).

In April 1977 a further two exotic species the Blue-green aphid *Acyrthosiphon kondoi* Shinji and Spotted alfalfa aphid *Therioaphis trifolii* (Monell) f. *maculata* appeared for the first time in Australia (Passlow 1977a, 1977b). By late 1977 they were widespread and in large numbers in the lucerne growing areas of eastern Australia and *A. kondoi* had reached Tasmania (Berg and Ridland 1978, Wilson *et al.* 1978, Cordingley *et al.* 1978, Forrester *et al.* 1978, Brieze-Stegeman 1978). A third exotic species the Pea aphid *A. pisum* appeared in Australia in 1979 (Walters and Brownlee 1980). There is an apparent trend toward world wide colonization of lucerne areas by these species (Smith 1959, Kain *et al.* 1977, Dürr 1981). The appearance of the exotic aphids led to the introduction of aphid parasitoids some of which have become widely distributed and the development of resistant cultivars; together with the breeding of other resistant lucerne types which are perhaps better suited to Australian conditions. Hunter River lucerne is still (1983) widely grown particularly to improve dryland pasture.

Some insect pest species and crop plants have been studied intensively but often little attention has been given to the community of which they form part (Pimentel 1961a, Pimentel and Goodman 1978). If pest management problems are to be seen in perspective it is essential to have some understanding of crop-based communities.

A community can be defined as a collection of diverse species occupying a space and interacting with each other and their physical environment (Moen 1973, Pielou 1975). McIntosh (1967) recognized that communities are difficult to delineate as they often merge with their neighbours. Even with crops, the range of many associated species will extend well beyond the edges.

Insect community studies can be placed into two groups: those involving a related group (or guild) of species (Room 1975, Rathcke 1976, Davidson and Roberts 1968, Speight and Lawton 1976) and those covering a wider range of species (Janzen 1973, Abbott 1976, Morgan and Southwood 1982, Pimentel 1961a, 1961b). My studies are of the second type as most attention was given to the common foliage-frequenting species of five insect orders and to the lucerne itself.

The aims of this study were: -

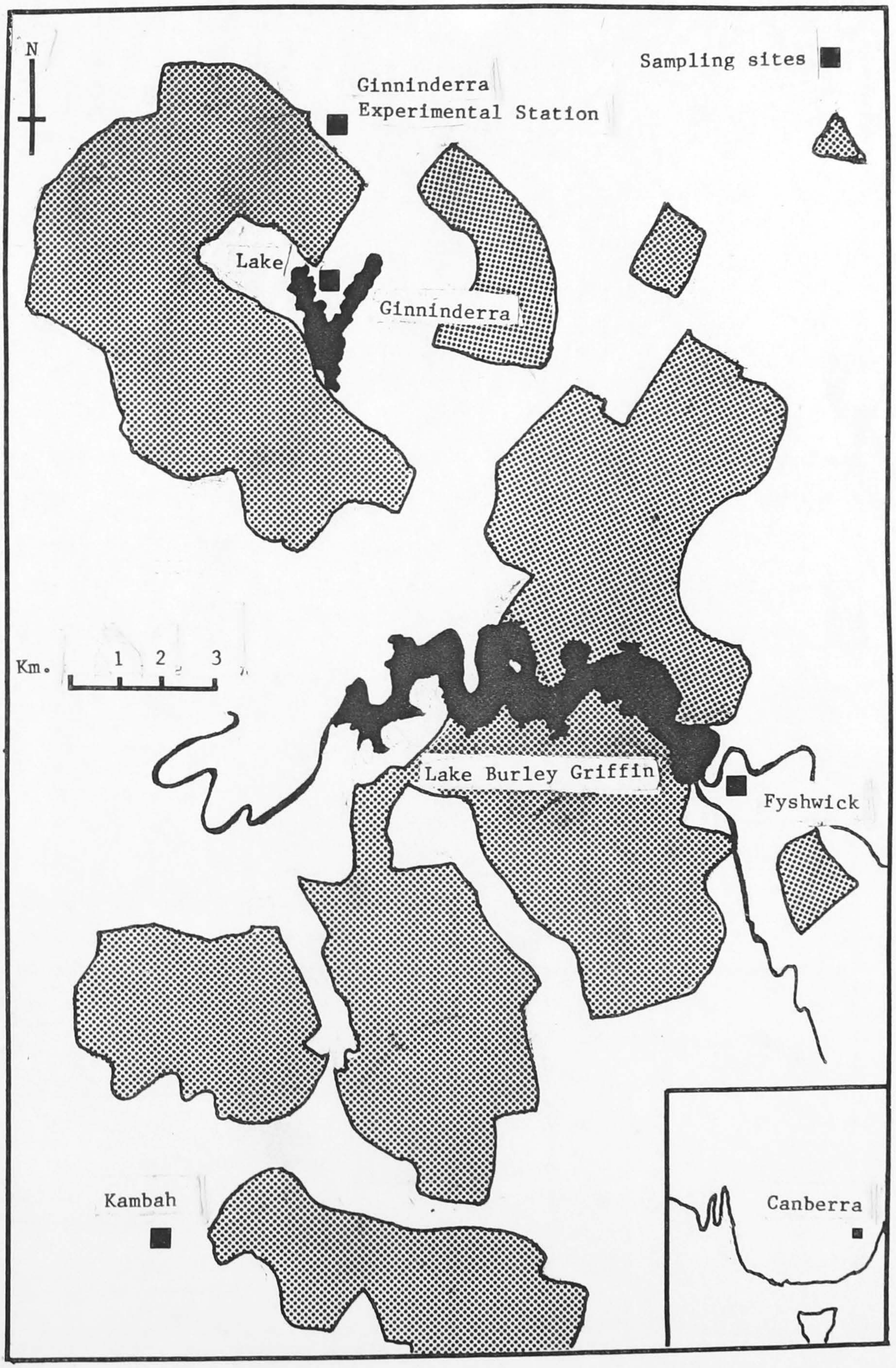
a) to monitor the seasonal changes in the insect community.

b) to assess the effects of lucerne cultivars on the insects;

TABLE 1. SAMPLING AREAS AND MANAGEMENT

SITE	HABITAT (Lucerne Cultivars)	MANAGEMENT
KAMBAH	1) Hunter River Lucerne	Dryland grazing and fodder.
	2) Grassland Pasture (cut)	Dryland grazing and fodder.
	3) Grassland Pasture (uncut)	Dryland grazing
FYSHWICK	1) Hunter River Lucerne	Irrigated: grazing and fodder.
	2) CUF 101 Lucerne	
LAKE GINNINDERRA	Hunter River Lucerne	Dryland, abandoned.
GINNINDERRA EXPERIMENTAL STATION	1) Hunter River Lucerne	Irrigated fodder. not treated with insecticide
	2) Condura 73 Lucerne	
	3) CUF 101 Lucerne	

FIGURE 1. Map of the Canberra area, showing sampling sites.

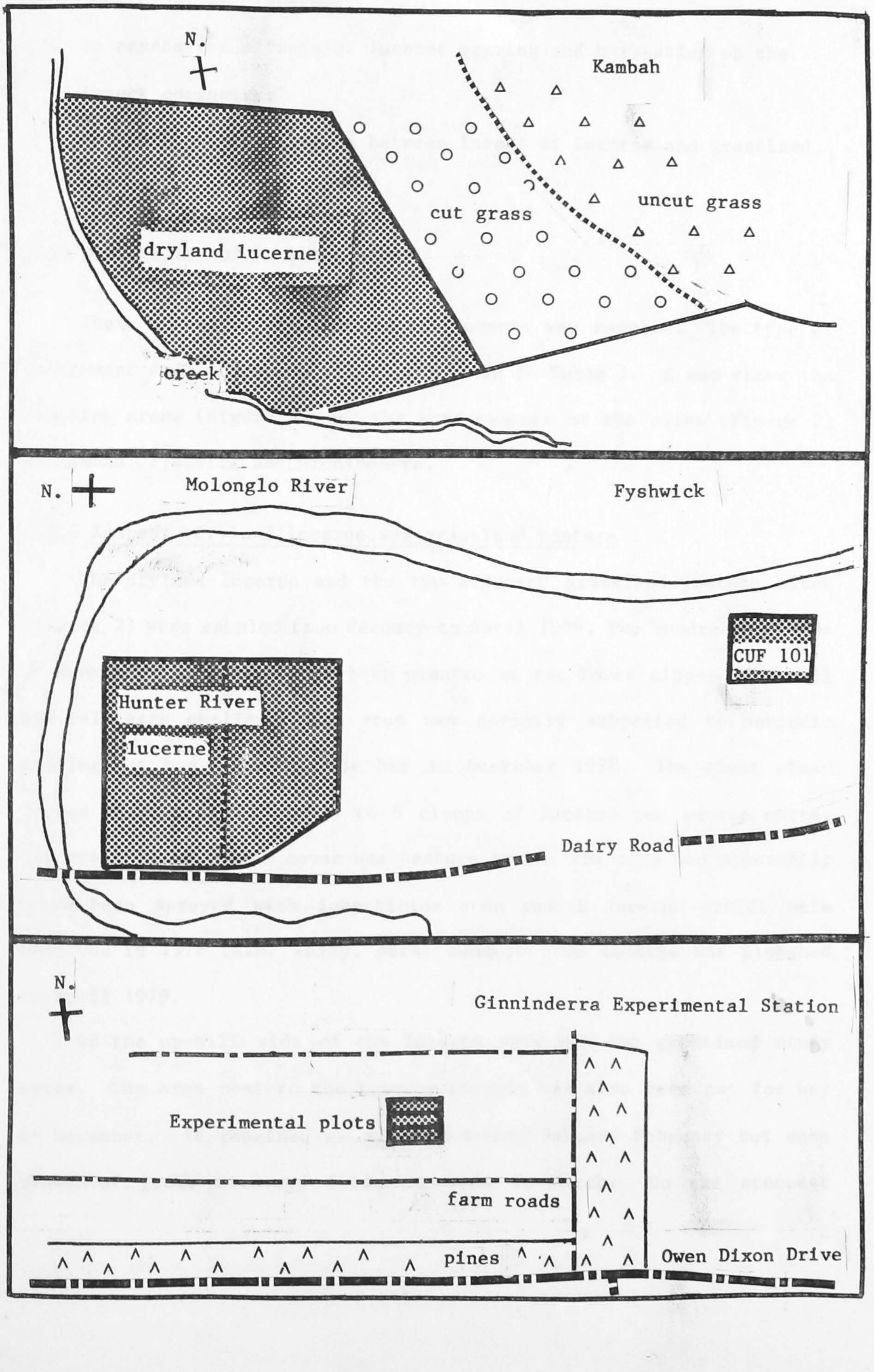


N
Sampling sites
Ginninderra
Experimental Station
Lake
Ginninderra
Km.
1
2
3
Lake Burley Griffin
Fyshwick
Kambah
Canberra

FIGURE 2. Plans of sampling areas at Kambah, Fyshwick and Ginninderra Experimental Station.

Scale for all three sites in m

100 200 300


N.
Kambah
dryland lucerne
cut grass
uncut grass
creek
N.
Molonglo River
Fyshwick
CUF 101
Hunter River
lucerne
Dairy Road
N.
Ginninderra Experimental Station
Experimental plots
farm roads
pines
Owen Dixon Drive

c) to compare the insect communities from irrigated and dryland 'Hunter River' lucerne;

d) to assess the effects of lucerne grazing and harvesting on the insect community;

e) to make some comparisons between insect of lucerne and grassland pasture.

1.2 DESCRIPTION OF SAMPLING AREAS

There were four areas where the lucerne was sampled. The type of management and lucerne cultivars are shown in Table 1. A map shows the sampling areas (Figure 1) and the arrangements of the sites (Figure 2) at Kambah, Fyshwick and Ginninderra.

1.2.1 Kambah: dryland lucerne and grassland pasture

The dryland lucerne and the two adjacent grassland pasture sites (Figure 2) were sampled from January to April 1979. Two hundred hectares of Hunter River lucerne had been planted at the lower slopes of a hill several years earlier. The crop was normally subjected to periodic grazing but had been cut for hay in December 1978. The plant stand varied in density between 4 to 8 clumps of lucerne per square metre. The predominant ground cover was pasture grass. The crop had apparently never been sprayed with insecticide even though lucerne aphids were observed in 1978 (K.M. Kelly, pers. comm.). The lucerne was ploughed in April 1979.

On the up-hill side of the lucerne were the two grassland study areas. The area next to the lucerne pasture had also been cut for hay in December. It remained as stubble during January February but some growth of grass occurred following rain in March. On the steepest ground was an area of uncut grass. The grass had grown to a height of about 0.75 m before 'haying off' in early summer 1978. There was no growth until the rain of March 1979.

1.2.2 Fyshwick: irrigated lucerne

Both lucerne crops at Fyshwick were on alluvial flood plains of the Molonglo River (Figure 1). About 200 ha of Hunter River were sown in the spring of 1978 and a further 60 ha of CUF 101 in September 1979 (Figure 2). The crops were cut for fodder about six times a year and periodically grazed by cattle mostly during the winter. The Hunter Lucerne was in two sections both of which were cut and treated with insecticide at different times during 1979.

1.2.3 Lake Ginninderra: dryland lucerne, abandoned

There was an area of about 1500 ha of dryland lucerne on the eastern side of the north-western arm of Lake Ginninderra (Figure 1). About 5 ha of the crop was used as a study area until it was ploughed in the summer of 1981 as part of "lake-side improvement". The lucerne was established when the area was still farm land and as it was being planted before other cultivars were widely grown, was assumed to be 'Hunter River'. The area had been acquired by the National Capital Development Commission before study was started in 1980.

The area was not subjected to any form of management. It is possible that some of the lucerne was self sown, though a few dryland lucerne crops in the Canberra area are viable for fifteen years or longer and the Lake Ginninderra crop could be that old.

1.2.4 Ginninderra Experimental Station (GES): irrigated lucerne

Three varieties of lucerne, Hunter River, Condura 73 and CUF 101 were grown in plots 50 x 30 m adjacent to each other (Figure 2) and managed as one crop. Condura and CUF are American varieties introduced after the appearance of lucerne aphids in Australia.

The plots were sown in the spring of 1978 and apart from an initial application of insecticide they had remained untreated until the end of the study in May 1982. The plots were spray irrigated during dry weather. Unlike commercially grown lucerne, the insects were the principal interest, so there tended to be longer periods between cutting of the crop.

2. GENERAL METHODOLOGY

2.1 INTRODUCTION

A major problem in the study of insect communities is the identification of all the species collected. Janzen and Schoener (1968) suggest that it is not always necessary to be able to identify species but this can restrict analysis because a margin of error of about 10% in species identification may be expected. This chapter describes an attempt to reduce this error margin and assess how these methods are likely to affect indices such as diversity.

The sweep and stem sampling techniques used during the study are described and a brief discussion of the use of two non-parametric statistical tests is also presented.

2.2 THE USE OF ENTITIES

Pimentel and Wheeler (1973) recorded about six hundred species of arthropods from lucerne crops in New York State USA but most of the species were scarce and many probably were not normally associated with the habitat. Any passing weather front is likely to deposit a variety of transient species in the lucerne crop (Freeman 1945, 1946; New 1975; Greve 1969) and their presence infers nothing about the lucerne arthropod community.

The juveniles of many insect species look quite different from the adult forms. Identification of juveniles can be difficult. Janzen (1973), Lamont (1975), Abbott (1976) and Murdoch *et al.* (1972), have based much of their analyses of arthropod communities on adult forms, including juveniles only when total numbers were calculated. Janzen and Schoener (1968) did include juveniles in the complete analyses of their Central American insect collections, but adults predominated in the collections, the study being made in the dry season. An entity system for classifying the insects on morphological type, mostly winged and apterous, was initially designed to overcome the problem of matching juveniles with adults of the same species. An insect with wings may have quite a different niche to an apterous form of the same species (Moreau 1976). In study of higher animals species have been equated with niche, though the appropriateness of this has sometimes been questioned (Hendrichson and Ehrlich 1971), for insect species which have apterous and winged forms such an equating seems untenable.

In an initial survey no attempt was made to identify the insects, instead each discrete type or 'entity' was given a code name. Ideally there were two entities for each species: an adult-winged form and a juvenile-apterous form, though in some species there were variations on this pattern so that more or less than two entities were listed. Sexual and social-class related morphological types were listed as separate entities but the entity classification with these species proved rather subjective.

In five months over 250 entities were collected and code-named. It was apparent that some rationalization of the entity system was necessary if it was not to become completely unmanageable. The relative abundances of the more common entities were calculated. The relative abundance values were then progressively summed, starting with the most abundant, until 90% of the total of collected individual insects were accounted for, this was then repeated using relative frequency. These were the criteria set to identify the most common entities which were identified as far as possible to species, but the entity system was retained and used as the basis for analysis. The presence of rare forms was recorded in subsequent studies but with the exception of some predatory species no details were recorded and the code system was not used. The rare predators were added to the list of species studied. The only other modification that had to be made concerned the lucerne aphids. Adult aphids can be winged or apterous: the apterous adults were placed with the juvenile.

With the reduction of the number of species being studied all but one of the sexual and social class related entities were eliminated from further study. The exception was an unidentified parasitic wasp a Tiphiidae where the female is apterous and the males winged. With the Collembola *Katianna australis* the adults were apterous so only one entity was recognized.

2.3 INDICES: THE EFFECT OF THE ENTITY SYSTEM

The methods used for summarizing data were: -

a) total numbers

b) richness

c) diversity, as expressed by the Shannon-Weaver formula (Shannon and Weaver 1949) and the Simpson-Yule formula (Simpson 1949).

d) similarity, as expressed by the Sørensen (1948) index and percentage similarity index (Southwood 1966).

Total numbers, the sum of all individuals were not affected by a change from a species to an entity classification. In contrast, richness, the total number of classes in a sample, was increased from 20 to 60 percent. Though there could be two or more entity-classes for a single species, often only one was present in a given sample so the increase in richness was always less than 100 percent.

The Shannon-Weaver formula for diversity is given by: -

$$H = - \sum \frac{n_i}{N} \log e \frac{n_i}{N}$$

and the Simpson-Yule index by: -

$$D = 1 \bigg/ \sum \frac{n_i\ (n_i - 1)}{N\ (N - 1)}$$

where n_i is the number in the ith class and N the total number in the sample. Diversity indices are an expression of their richness and evenness components (Pielou 1969, Sheldon 1969, Tramer 1969). Diversity can also be expressed as the shape of ranked distribution curves (May 1975). Such curves are obtained by plotting on a graph the relative abundance of the classes from highest to lowest. A geometric distribution with 80% of the relative abundance being accounted for by the sum of the first few species in the series, is indicative of low diversity. When the curve approaches a line with nearly constant slope this is indicative of high diversity. Comparisons using species and entities as classes shows that the resulting ranked distribution curves for entities is always flatter than that for species which shows that regardless of what index is used, the diversity values will always be higher with entities. With the lucerne insects, the entity system mainly increased the richness, rather than evenness because within most species one form tended to be far more numerous than the others.

Whittaker (1972) said that the Shannon-Weaver index is influenced more by the middle ranking classes, in contrast to the Simpson-Yule index which is greatly influenced by the most abundant classes. Whittaker (1972) considered this to be a fault in the Simpson-Yule index but it is the most abundant classes which have the greatest influence on the shape of the ranked distribution curves. Rare species have little or no importance on this diversity index (N.B. $(n_i - 1)/(N - 1) = 0$ when $n_i = 1$).

The Simpson-Yule index is preferable when the rare classes have been virtually eliminated from the samples. I have used the Shannon-Weaver index only when the results needed to be tested by using a different method of calculating diversity.

The Sørensen (1948) similarity index is given by: -

$$Q_S = \frac{2w}{(a + b)}$$

where a and b are numbers of classes listed for sample A and B respectively and w is the number of classes found in both samples. When the classes are entities the values of all three variables will always be greater than for species but the increase in 2w may be cancelled out by a proportional increase in (a + b). In practice the behaviour of Qs (entities) and Qs (species) for a series of samples does not follow a predictable pattern.

Percentage similarity is given by: PS = $\sum$ of minimum percentages, (Southwood 1966). The relative abundance as percentages for each class per sample is calculated and the smallest values for each class are summed. The effect of using entities in preference to species tends to decrease PS values as the number of classes and therefore potential differences are increased.

With the Sørensen index each entity is given equal weight so that collectively the rarities can have a significant effect. The index was only used in analysis of the results from the initial survey where all the entities collected were listed. When most of the rarities were eliminated from later studies the PS index was used, as rarities have little influence on the results.

2.4 WILCOXON SIGN-RANK AND TWO SAMPLE TESTS

Insect distribution has a tendency to follow a negative binomial distribution (Southwood 1978, Evans 1953). This factor and fluctuations in numbers due to environmental effects tends to produce large variances. To overcome these problems the non-parametric Wilcoxon sign-rank and Wilcoxon two sample tests (Sokal and Rohlf 1969) have been used. The sign-rank test is used unless otherwise stated. It is equivalent to the paired t test and the two sample tests to the Student's t test. All analyses using these non-parametric tests were done on a two-tailed basis.

2.5 SAMPLING METHODS

There does not seem to be any sampling method which is particularly suited to the study of insect communities. Different methods will tend to favour some species more than others, so that sampling methods used have to be a compromise.

2.5.1 Sweep net sampling

Sweep sampling was used extensively in this study, only a general account is given here. Two types of net were used; the first was a 'pond net' type with a triangular mouth (0.3 x 0.3 x 0.3 m), a handle 1.5 m long and a bag depth of 0.45 m. The side of the net furthest from the junction of the frame and handle was held parallel with the ground, as the net was moved rapidly through the vegetation in a tight "figure of eight" motion, while I walked along holding the net handle in both hands. The net was twisted during this action so that the mouth was always facing the direction of travel. The net was not lifted more than 0.25 m from the ground while sweeping. This technique was particularly suited to sweeping low vegetation including lucerne stubble.

The second type of net had a round hooped mouth 0.43 m in diameter a bag depth of 0.65 m and a short handle of 0.13 m. Sampling was done using only one hand, passing the net through the crop in a "figure of eight" pattern keeping the mouth in the direction of travel. This type of net was more suitable for sampling taller vegetation. The bigger bag and wider mouth meant that larger samples could be taken but the round mouth reduced efficiency when sweeping close to the ground. Lucerne stubble could not be swept as only a small fraction of the net mouth would make contact with vegetation. Samples from the two types of sweep net were not comparable.

Sweep net samples were treated in one of three ways: -

a) in the initial survey they were placed in plastic bags sealed and on returning to the laboratory were frozen to -10°C. After being thawed the samples were placed in trays, much of the vegetation removed and the insects identified and counted.

b) the samples were bagged and frozen as above but the samples were then placed in warm water, the vegetation removed and the insects filtered out by pouring the water through fine gauze.

c) the samples were placed in 70% ethanol as soon as they were taken. The insects were then extracted in the field as for b).

The advantages for the method a) was that samples with much fine dry vegetable matter could be processed. Some of the samples were from non-irrigated pasture which resulted in much fine debris being collected. Methods b) and c) were more suitable for irrigated lucerne.

The advantage of b) was that less time needed to be spent in the field but with c) there were no bulky storage problems.

Problems with sampling insects on foliage results from some species being highly mobile while others are difficult to remove. Nielson (1957) found when sweeping that some Spotted alfalfa aphid could be left on the lucerne after sampling. DeLong (1932) determined that when sweep sampling, highly mobile jassids, results varied with weather and host plant conditions. Observations and stem sampling showed (Chapter 6) that when the lucerne was short the insects were distributed from ground level to the top of the plant, but with taller stems most were found within the top 150 mm of the foliage. There were no species specifically associated with the lower part of tall stems. Measurement of plant damage caused by sweeping showed that the nets of either design did not penetrate much more than 150 mm into the top of a tall lucerne crop, which is where the greatest concentration of insects are to be found. With short crops the problem of penetration does not arise except that round mouthed nets will become inefficient when sampling close to the ground. It is felt that providing extreme weather conditions are avoided, sampling errors from the sweeping methods are not likely to be so great as to give misleading results. There is an advantage in being able to obtain comparatively comprehensive samples with a single operation.

2.5.2 Stem sampling: plant and insect

Stem sampling is considered to be the best way to census comparatively inactive species like aphids (Nielson 1957), but cannot be used to give a comprehensive view of an insect community though it can give valuable information about some of the species in the community.

Whole stems of lucerne were taken as part of the process of measuring plant characteristics. With insect stem samples two methods were used, the first involved examining stems *in situ*. The plant stem was carefully examined from the ground up so that if any insects were dislodged they fell onto the ground or on foliage already examined. The plants were divided into sections by means of a marked stick placed along side the plant. The sections were in terms of distance from the ground: -

Section	1	0 - 199 mm
	2	200 - 399 mm
	3	above 400 mm.

During sampling the number of insects in each vertical section and the type of site occupied, i.e. under leaf, top of leaf, shoot and stem, were recorded.

Another method used cut stem samples, in this the sections were reduced from 200 to 100 mm and continued in 100 mm sections above the 400 mm mark. Samples were taken only from lucerne growing in rows. A variation of this method was used when specific parts of the plant, such as flowers were sampled. A 0.25 m section of the row was selected and ten stem sections were taken from the top-most part of the plants and sealed in a plastic bag. Cutting and handling of the stem section was done carefully so as not to disturb the insects until the samples were in the bag. Tweezers and fine scissors were used and samples were taken from each 100 mm section all the way to ground level. As the stems varied in height the sampling method resulted in a step like pattern being cut into the side of the row.

The disadvantages with *in situ* stem sampling were that it was slow and small insects could be overlooked. With cut stem samples examination could be made in the laboratory after the insects had been killed and removed by washing the stems. The disadvantage with the method was that the sites occupied by the insects went unrecorded.

2.53 Suction machine sampling

A "Burkard 1.25T" suction-sampling machine was used to a limited extent for sampling small plots. The samples contained a lot of plant debris so they were frozen and then dry sorted using the tray method. The machine was found to be difficult for one person to operate.

3. IRRIGATED AND DRYLAND LUCERNE WITH COMMENTS ON GRASSLAND PASTURE

3.1 INTRODUCTION

Dryland lucerne is grown extensively in southern Australia to improve grassland pasture. Lucerne aphids usually cause the greatest problems with irrigated lucerne and it is these crops which have been studied the most, although often irrigation is not specified (Frazer *et al.* 1981, Howell and Pienkowski 1971, Pimentel and Wheeler 1973, Walters and Dominiak 1978). Aphids have the potential to cause much damage to dryland crops given the right conditions (Bishop *et al.* 1980, Allen 1978). The usually low relative humidity, slow plant growth and periods when little or no vegetation is above ground, makes the dryland lucerne a tenuous environment for insects. Murdoch *et al.* (1972), Schoener and Janzen (1968) and Lawton (1978) have shown that humidity, patterns of plant architecture, and the insect species distribution largely determine the character of an insect community.

The aim here is to compare insect samples from dryland and irrigated Hunter River lucerne. Grassland pasture communities were also examined in order to permit comparison with the lucerne. The study encompasses all the work done in an initial survey in 1979, as well as some in 1980-81. Two other cultivars were studied, although they were not being grown under dryland conditions. A comparative study was made to determine the extent of changes in the insect community during the day and night which involved sampling of the irrigated CUF 101, as well as the Hunter River lucerne, at Fyshwick.

TABLE 2. LIST OF SPECIES AND ENTITY CODED NAMES.

SPECIES	ENTITIES WINGED	APTEROUS
COLEOPTERA		
Cantharidae		
Chauliognathus lugubris (F.)	C8	C8A
Chrysomelidae		
Longitarsus sp.	C19	-
Coccinellidae		
Coccinella repanda Thunberg	C4	C4A
Diomus notescens Blackburn	C7	C7A
Henosepilachna sp. (rare)	C28	
Curculionidae		
Sitona humeralis Stephens	C12	-
Graphognathus leucoloma (Boheman)	C13	-
Lathridiidae		
Melcrophthalma australis Blackburn	C2	-
Corticaria adelaidae Blackburn	C1	-
Melyridae		
Dicranolaius bellulus Guerin-Meneville	C9	-
HEMIPTERA		
Aphididae		
Acyrthosiphon pisum Harris	L54	L54A
Acyrthosiphon kondoi Shinji	L44	L44A
Aphis craccivora Koch (rare)	L59	L59A
Therioaphis trifolii (Monell)	L46	L46A
Lygaeidae		
Cryptorhamphus sp.	L21	L21A
Nysius vinitor Bergroth	L1	L2

SPECIES	ENTITIES	
	WINGED	APTEROUS
Membracidae		
Anzac sp.?	L41	-
Miridae		
Campylomma livida Reuter	L49	L49A
Creontiades dilutus (Stål)	L11	L11A
Cicadellidae		
Orosius argentatus (Evans)	L43	L43A
Unidentified sp.	L47	L47A
Unidentified sp.	L45	L45A
Unidentified sp.	L40	L40A
Nabidae		
Tropiconabis capsiformis (Distant)	L3	L4
Pentatomidae		
Cermatulus nasalis (Westwood)	L12	L12A
Oechalia schellenbergii Guerin-Meneville	L7	L7A
COLLEMBOLA		
Sminthuridae		
Katianna australis Womersley		K8

N.B. *Sminthurus viridus* L. has not been recorded in this part of Australia.

DIPTERA		
Syrphidae		
Simosyrphus grandicornis (Macquart)	D5	D7

SPECIES	ENTITIES	
	WINGED	APTEROUS
HYMENOPTERA		
Apidae		
Apis mellifera L.	H22	
Braconidae		
Chelonus sp.	H7	-
Microdus sp.	H34	-
Ichneumonidae		
Epiborus sp.	H4	
**Campoletis* sp.	H8	
Diplazon laetatorius (F.)	H14	
Tiphiidae		
unidentified sp.	H54	H48
LEPIDOPTERA		
Geometridae		
Zermizinga indocilisaria Walker	S2	S2A
Lycaenidae		
Lampides boeticus (L.)	S4	S4A
Noctuidae		
Heliothis punctigera Wallengren	S1	S1A
NEUROPTERA		
Chrysopidae		
Chrysopa spp. (rare)	N2	N2A
Hemerobiidae		
Micromus tasmaniae (Walker)	N1	N1A
Mantisphidae		
unidentified sp. (rare)	N3	-

SPECIES	ENTITIES	
	WINGED	APTEROUS
ORTHOPTERA		
Acrididae		
Gastrimargus musicus (F.)	A2	A2A
Phaulacridium vittatum (Sjöstedt)	A1	A1A
THYSANOPTERA		
Thripidae		
Thrips imaginis Bagnall	T2	T2A
Thrips tabaci Lindeman	T3	T3A

* A dark and light abdomen types of *Campoletis* sp. were recognised. It is uncertain if these were two separate species or one species, the colour being related to temperature (Liu and Carver 1982). The dark coloured type was rare.

3.2 METHODS

The initial survey was made at Kambah and Fyshwick between January and May 1979. The habitats sampled were the uncut grassland, cut grass and dryland lucerne at Kambah and the irrigated Hunter River lucerne at Fyshwick (Figure 1, 2). Each habitat type had four area replicates of 100 x 50 m about 50 m apart. A triangular-mouthed net was used for sampling because some of the vegetation was short (Ch 2.5.1). Three samples of 30 sweeps were taken from each replicate area once a week, between 1030 and 1300 hrs each day. When possible sampling was carried out in fine sunny weather, never in wet or excessively windy conditions. The insects in the samples were killed by freezing and were removed from the vegetation by using the large tray method (Ch 2.5.1).

A second series of samples were taken from the lucerne in the Ginninderra area between November 1980 to October 1981. Sweep samples were made with the round-mouthed net (Ch 2.5.1) which is more suitable for collecting in taller vegetation. Insects were killed by freezing and removed from the plant debris by washing.

3.3 RESULTS

A list of most common species from the initial survey is given in Table 2; in addition to these, about another 200 rare entities were recorded but not formally identified (Ch 2.2).

Prior to the start of the project, thunder showers in December 1978 had stimulated the lucerne to produce stems up to 300 mm high in the dryland lucerne at Kambah. The grass in the area had formed hay and did not respond to the rain. Later rains in March and April 1979 produced growth of the pasture grasses as temperatures were lower

FIGURE 3. Fluctuations in total insects per sweep sample from
(a) dryland lucerne and cut grass, Kambah
(b) irrigated lucerne, Fyshwick and uncut grass Kambah.
Also (c) maxima and minima temperatures and
(d) daily rainfall, January to May 1979.

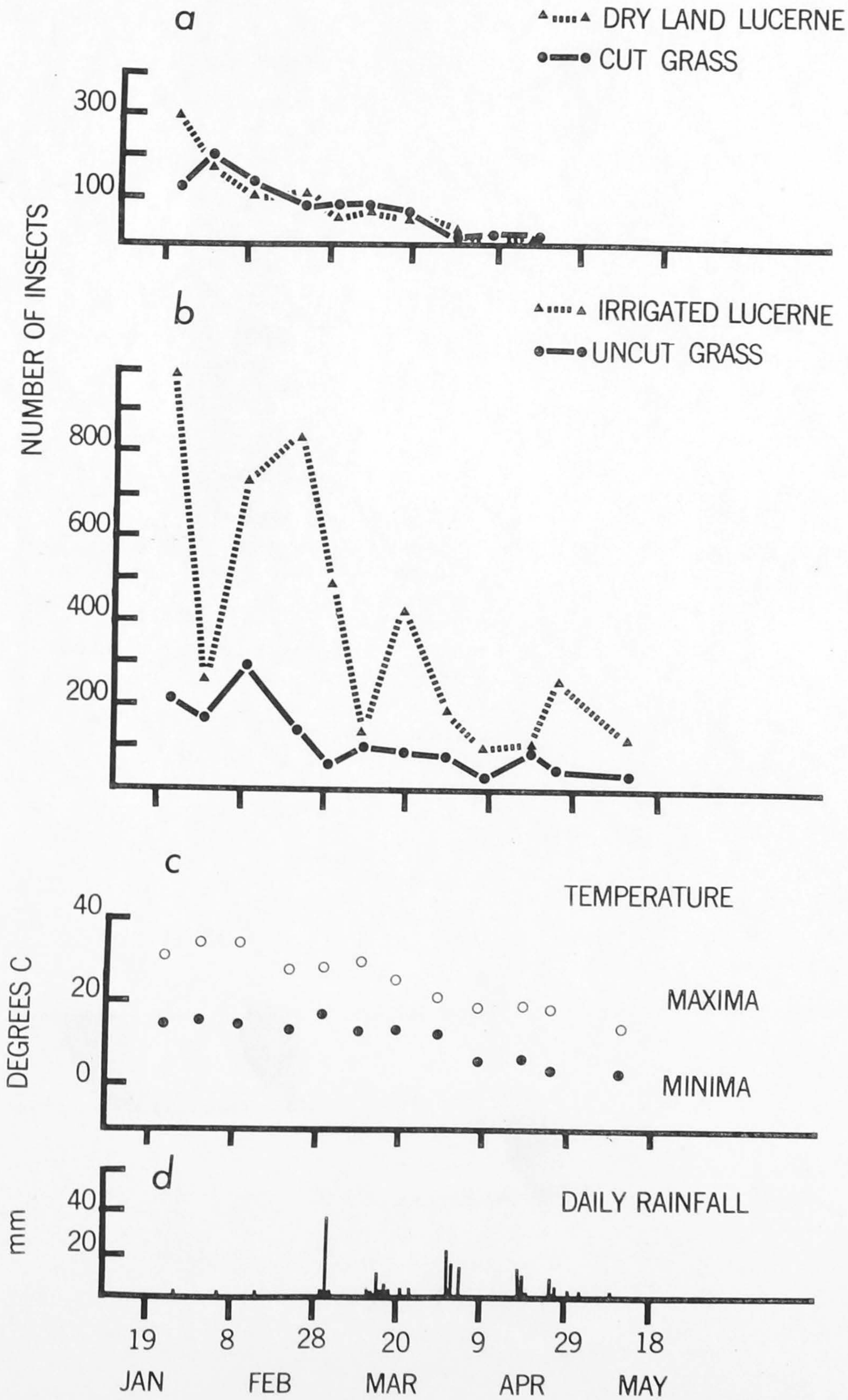
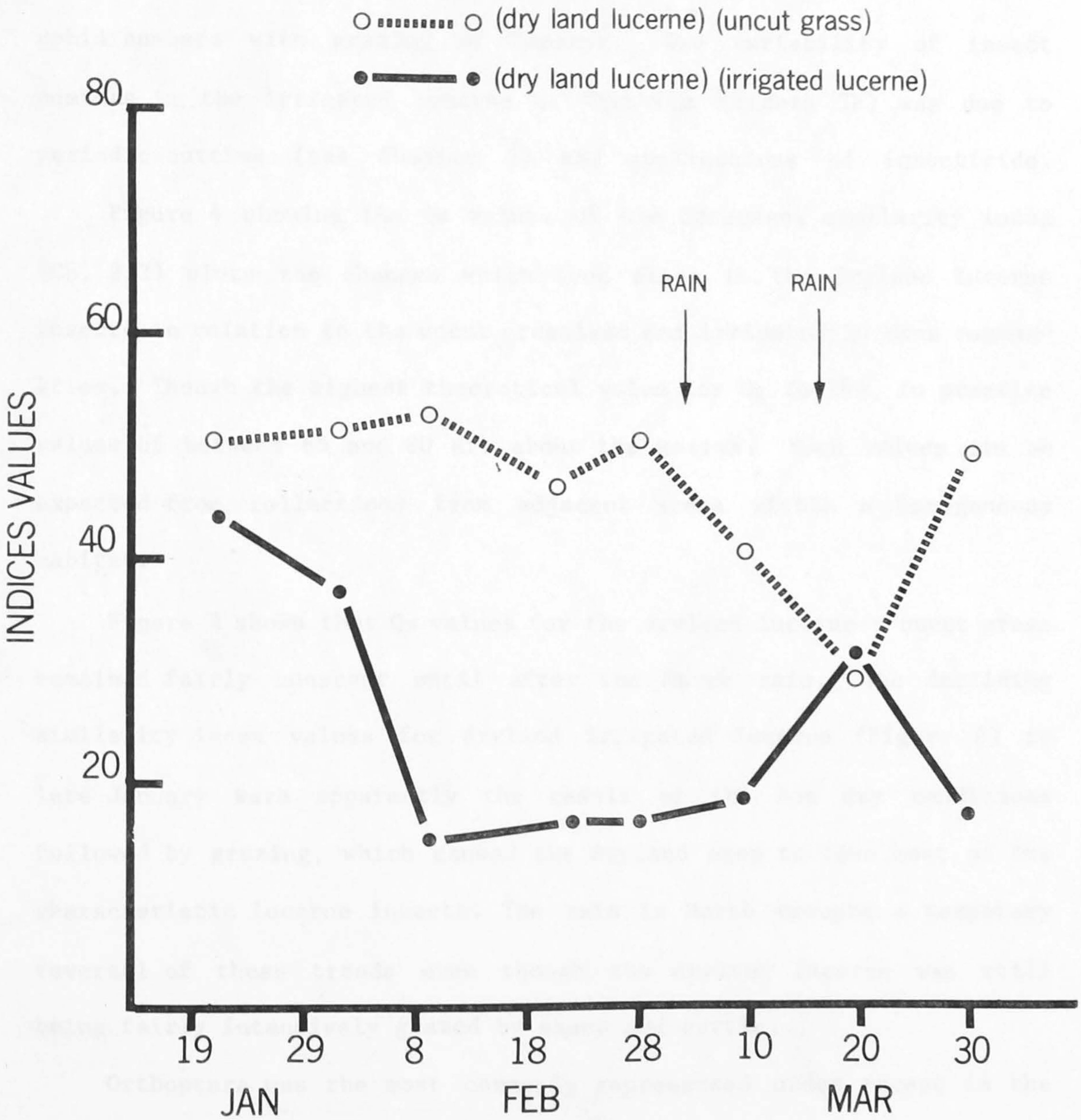

a
DRY LAND LUCERNE
CUT GRASS
300
100
NUMBER OF INSECTS
b
IRRIGATED LUCERNE
UNCUT GRASS
800
600
400
200
c
TEMPERATURE
40
20
0
DEGREES C
MAXIMA
MINIMA
d
DAILY RAINFALL
40
20
mm
19
8
28
20
9
29
18
JAN
FEB
MAR
APR
MAY

FIGURE 4. Qs similarity index values between
(1) dryland lucerne and uncut grass, Kambah, and
(2) dryland lucerne, Kambah and irrigated lucerne, Fyshwick.
January to March 1979.


(dry land lucerne) (uncut grass)
(dry land lucerne) (irrigated lucerne)
80
60
40
20
INDICES VALUES
RAIN
RAIN
19
29
8
18
28
10
20
30
JAN
FEB
MAR

(Figure 3). There was a decline in numbers of insects from January to May in all four sampling areas, probably related to the reduction in temperature with the onset of autumn (Figure 3a, b) but in the dryland lucerne the decline may also be due to grazing which started in late February, Bishop *et al.* (1980) observed a similar decrease in Blue-green aphid numbers with grazing of lucerne. The variability of insect numbers in the irrigated lucerne at Fyshwick (Figure 3b) was due to periodic cutting (see Chapter 5) and applications of insecticide.

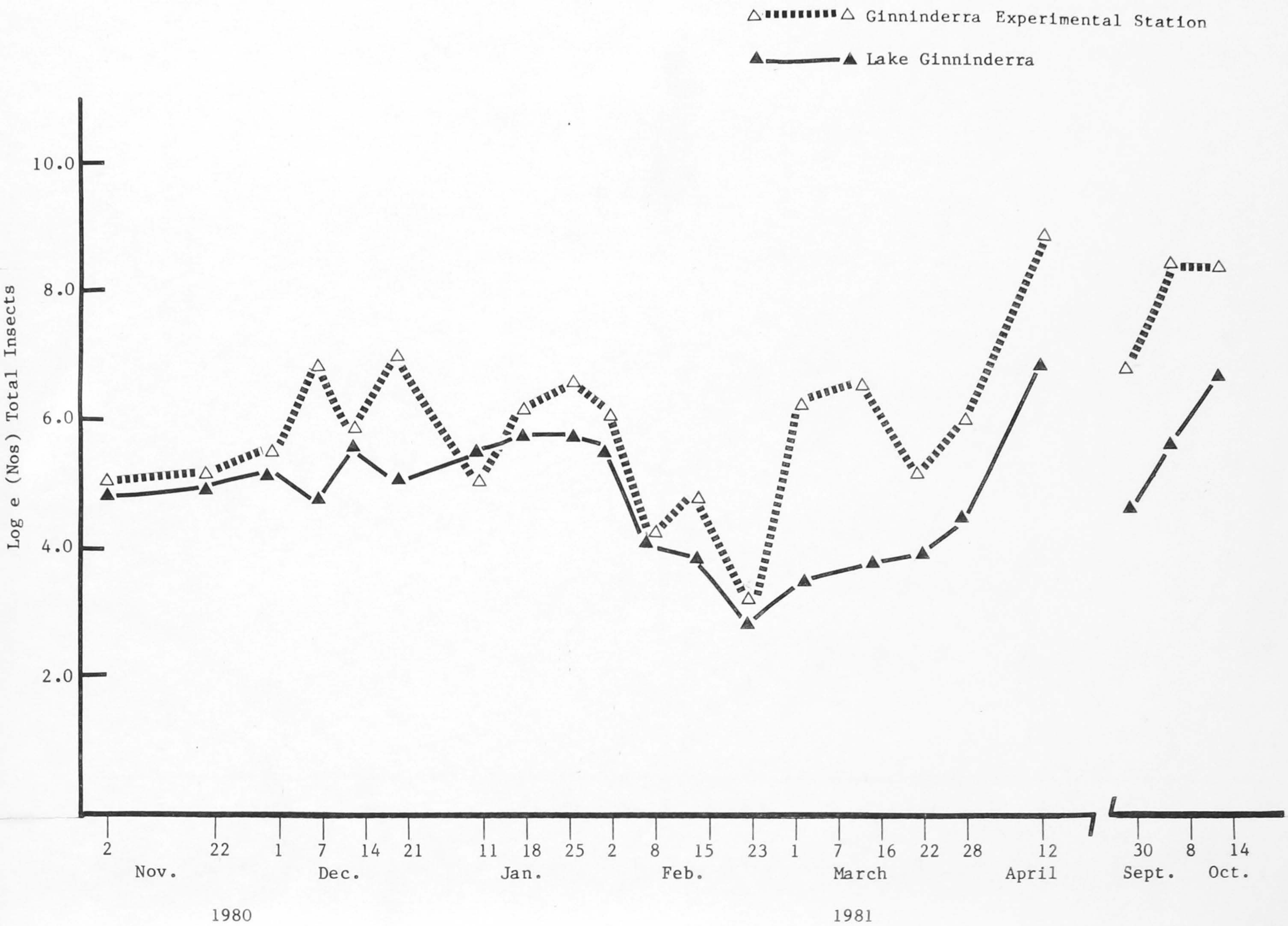
Figure 4 showing the Qs values of the Sørensens similarity index (Ch. 2.2) plots the changes which took place in the dryland lucerne insects in relation to the uncut grassland and irrigated lucerne communities. Though the highest theoretical value for Qs is 100, in practice values of between 65 and 80 are about the maxima. Such values can be expected from collections from adjacent areas within a homogeneous habitat.

Figure 4 shows that Qs values for the dryland lucerne - uncut grass remained fairly constant until after the March rain. The declining similarity index values for dryland irrigated lucerne (Figure 4) in late January were apparently the result of the hot dry conditions followed by grazing, which caused the dryland crop to lose most of the characteristic lucerne insects. The rain in March brought a temporary reversal of these trends even though the dryland lucerne was still being fairly intensively grazed by sheep and cattle.

Orthoptera was the most commonly represented order except in the irrigated lucerne where it was replaced by Hemiptera. The dryland lucerne samples also contained a high proportion of winged Coleoptera.

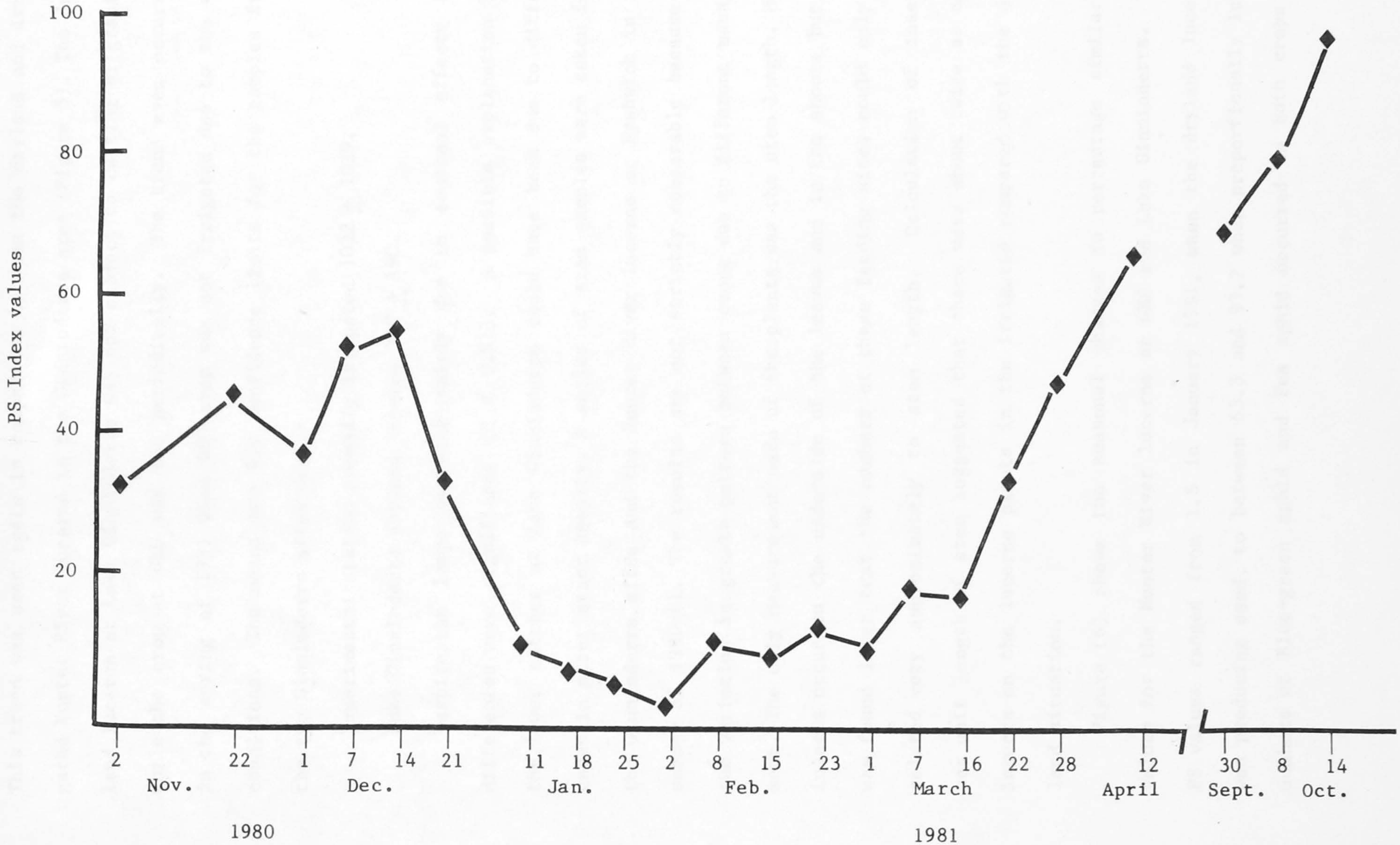
During the initial survey it was found that the numbers of insects collected from the dryland lucerne were lower than from irrigated crops.

FIGURE 5. Numbers of insects per sweep sample collected from Hunter River lucerne at Ginninderra Experimental Station.



Ginninderra Experimental Station
Lake Ginninderra
Log e (Nos) Total Insects
10.0
8.0
6.0
4.0
2.0
2 22 1 7 14 21 11 18 25 2 8 15 23 1 7 16 22 28 12 30 8 14
Nov. Dec. Jan. Feb. March April Sept. Oct.
1980
1981

FIGURE 6. Percentage similarity values - Hunter River lucerne Ginninderra Experimental Station and Lake Ginninderra.



PS Index values
100
80
60
40
20
2
22
1
7
14
21
11
18
25
2
8
15
23
1
7
16
22
28
12
30
8
14
Nov.
Dec.
Jan.
Feb.
March
April
Sept.
Oct.
1980
1981

This trend was seen again in comparison between the dryland and irrigated Hunter River lucerne in the Ginninderra area (Figure 5). The dryland lucerne at Lake Ginninderra was not subject to cutting or grazing while the crop at GES was cut periodically. The trend even occurred in the spring of 1981 when GES crop was not irrigated due to the wet conditions. The means and 95% confidence limits for the samples from the two Ginninderra sites were:-

Experimental station normally irrigated 1032 $\pm$ 1039.

Lake Ginninderra dryland lucerne 210 $\pm$ 190.

Despite the large variance mainly due to seasonal effects the differences were significant ($P < 0.01$). A possible explanation for the lower catches at Lake Ginninderra could have been due to differences in plant stand density. A series of stem samples were taken from the Ginninderra sites and the Hunter River lucerne at Fyshwick in the summer of 1980-81. The results are not strictly comparable because of the variation in growth pattern between crops due to different management. The only measurement made of the plants was the stem length. Most insects occur on the underside of the leaves and in the shoots but it was found later that the numbers of these feeding sites could only be related very approximately to stem length. Calculation of insects per unit length of stem suggested that there were about twice as many insects on the lucerne plants in the irrigated compared with the dryland situation.

Figure (6) shows the seasonal changes in percentage similarity values for the Hunter River lucerne at GES and Lake Ginninderra. The PS values ranged from 1.6 in January 1981, when the dryland lucerne was producing seed, to between 63.3 and 93.2 when proportionally large numbers of Blue-green aphid and Pea aphid occurred in both crops in autumn and spring 1981.

Sweep samples were normally taken in daylight but night samples might show other aspects of the insect community in terms of types of entities and numbers. It was also possible that any diurnal patterns could alter as conditions in the crop change between cycles of cutting. Between 22 January to 15 February 1980 a series of five, day and night samples were taken from the Hunter River and CUF 101 lucerne crops at Fyshwick. On the sampling day forty samples of 30 sweeps were obtained, ten each from 'Hunter River' and CUF at night from 2000-2400 hr and in the day from 1030-1530 hrs. The triangular-mouthed net was used as before but at night no light was shown because this might have attracted insects to the net.

Both crops were recovering after being cut a few days earlier, the CUF was more advanced in height than the Hunter River lucerne. Sampling was continued through a period of increasing plant height and insect numbers until the next cutting, on the 14 February for CUF and 17 February for Hunter River.

Adult White fringed weevil *Graphognathus leucoloma* were recorded more frequently at night from both crops.

FREQUENCY OF WHITE FRINGED WEEVIL ADULTS

Cultivar	Day	Night
Hunter River	2	14
CUF 101	0	13

Otherwise, there was little difference between the day and night samples in terms of the number of insects or the types of entities.

TABLE 3. NUMBERS OF INSECT PER SAMPLE AND 95% CONFIDENCE LIMITS, DAY AND NIGHT SWEEP SAMPLES FYSHWICK

Means are for ten sweep samples. Taken from 22 January to 15 February 1980.

	CULTIVARS			
DATE	HUNTER RIVER		CUF 101	
	DAY	NIGHT	DAY	NIGHT
22 Jan	2.5 $\pm$ 1.6	6.3 $\pm$ 4.3	8.5 $\pm$ 4.5	9.7 $\pm$ 4.8
28 Jan	5.3 $\pm$ 1.7	13.9 $\pm$ 4.9	13.8 $\pm$ 7.4	21.1 $\pm$ 7.1
4 Feb	11.7 $\pm$ 6.5	10.3 $\pm$ 2.6	32.9 $\pm$ 9.9	21.6 $\pm$ 5.1
9 Feb	11.6 $\pm$ 4.6	18.0 $\pm$ 6.4	60.6 $\pm$ 21.1	76.2 $\pm$ 18.5
15 Feb	29.5 $\pm$ 13.4	38.3 $\pm$ 8.5		

Table 3 shows the number of insects collected per 10 samples and the 95% confidence limits.

A problem with sweeping at night is that the crop may be damp which can affect the results. Damp vegetation causes the sweep net to fill more rapidly with plant debris so that at the end of 30 sweeps the catching ability can be greatly reduced. However, the technique may be more efficient in the early stages of sweeping, insects become stuck to the damp net or plant debris and are less likely to escape. When comparing the numbers of insects (Table 3) obtained in day and night samples of this type, a higher than normal sampling error must be expected.

3.4 DISCUSSION

During the summer of 1979 severe conditions for many insects existed at the grassland pasture sites at Kambah. There was practically no green vegetation and relative humidity even at ground level would usually have been low. The total number of insects collected (Figure 3) was lower than the irrigated lucerne at Fyshwick. Few insects with sucking mouth parts were captured from the grassland and those that were appeared to have been predators. In contrast sucking mouth-part type insect were common in the irrigated lucerne. Most insects at the Kambah grassland sites were forms with biting mouth parts, these were proportionally less well represented in the Fyshwick lucerne. These observations are consistent with those of Janzen and Schoener (1968) in their study of Central American sites during the dry season, where they found a higher proportion of biting types in the dryer areas. Sucking insects are liquid feeders, which put herbivorous types at a disadvantage in some seasons when the top growth of plants dried off.

Schoener and Janzen (1968), Janzen and Schoener (1968) established that under desiccating conditions the insect species tended to be larger; a trend also seen in the comparison of the grassland and irrigation lucerne collections from Kambah and Fyshwick. Larger insects have a lower surface-area to volume ratio and many of the grassland pasture species also had particularly thick cuticles, features which make water retention easier.

The Kambah dryland lucerne had two major components in the insect community, one associated with grassland pasture and the other with lucerne. The lucerne component consisted of such plant-feeding types as aphids and several species of mirid. The grassland component was numerically dominated by Orthoptera. When grazing started in February 1979 the grassland section of the community was relatively unaffected; the Sørensen index values (Figure 4) for dryland lucerne x uncut grass, remained fairly constant until the rain of March. The lucerne-associated section of the community was affected by the grazing and the index values for dryland x irrigated lucerne dropped sharply in late January (Figure 4).

The dryland lucerne at Lake Ginninderra had the typical lucerne section of the insect community present throughout the time although the proportions of some of the entities in the samples was sometimes very different from the irrigated Hunter River lucerne nearby at GES. Species like *Thrips imaginis* and the mirid *Campylomma livida* were in unusually large numbers at times, and it appeared that lucerne flowers were attracting these species. The irrigated lucerne was cut at the early stages of flowering but the Lake Ginninderra crop had been abandoned, so flowering could proceed unhindered.

Despite the attraction of flowers to some insects, numbers in the dryland lucerne were usually lower than in the Hunter river crop at GES (Figure 5), even during the wet spring of 1981 when GES lucerne was not irrigated. The effect of cutting on GES and lower plant stand density at Lake Ginninderra may in turn have affected the results from sweep samples. The limited amount of stem sampling from both sites suggested that the lower plant stand density at Lake Ginninderra was not able to account for the significantly lower numbers of insects. This is a subject worthy of further investigation. Cutting may temporarily reduce insect numbers but it induces the plant to produce what is probably more palatable vegetation but without the proliferation of flowers favoured by some species. Bishop *et al.* (1980) found in plot experiments that the numbers of Blue-green aphids on lucerne which had recovered from cutting were higher than on an adjacent uncut control area.

Figure (6) shows a very wide range in the percentage similarity index. Very low values of the index in January 1981 occurred at a time when the dryland lucerne of Lake Ginninderra had produced seeds. In contrast, the GES plots rarely produced seed because of periodic cutting.

The results from the night and day sweep samples suggest that there are no substantial diurnal changes in the insect entity composition of the lucerne crop. This could be the result of the rather brief evolutionary history of the community which may have left many of the potential temporal and spatial niches unoccupied. Vicherman and Sunderland (1975) in England described significant changes in the numbers of species incident in day and night samples from cereal crops, but cereals have been grown longer in England than lucerne in Australia.

4. INSECTS: EFFECTS OF CULTIVARS AND SEASONS

4.1 INTRODUCTION

A number of studies have been made of the seasonal and cultivar effects on lucerne arthropods, most of which were of individual species (Hughes 1978, Smith 1959) or groups of species (Neuenschwander *et al.* 1975, Wiegert 1965, Milne 1978, Gutierrez *et al.* 1980). Very little information on the seasonal changes of community composition has been published (Pimentel and Wheeler 1973) and none apparently from Australia.

The aim here is to describe the seasonal and cultivar effects on the lucerne insect community at Ginninderra Experimental Station (GES). There are two ways in which the insects are affected: directly by physical environmental factors and indirectly through the lucerne plant which itself responds to physical factors such as temperature and day length. The effects of periodic harvesting are discussed in the next chapter.

The lucerne cultivar CUF 101 and to a lesser extent Condura 73 have an antibiosis towards lucerne aphids (Nielson and Lehman 1980) although Bishop *et al.* (1982) regarded the resistance in CUF 101 as no more than tolerance (Lodge *et al.* 1980). Dr R.D. Hughes (pers. comm.) found that in winter when attempting to rear Spotted alfalfa aphids on cut CUF 101 shoots from GES in the laboratory, resistance of individual plants ranged from highly resistant to susceptible. The antibiosis in lucerne foliage is attributed to saponin (Sutherland *et al.* 1975, Armburst *et al.* 1980), but it is uncertain that this is the only chemical involved. Duke (1981) lists thirteen other possible toxins

TABLE 4. SEASONAL LUCERNE GROWTH PERIODS GINNINDERRA EXPERIMENTAL STATION

A period cover all stages of crop growth from lucerne stubble to the tall stem flowering stage.

GROWTH PERIODS (Seasons)		NO. OF SWEEP SAMPLES TAKEN DURING EACH PERIOD
Autumn 1980	18 March - 30 April 1980	12
Winter 1980	7 May - 10 September 1980	32
Spring 1980	1 October - 12 November 1980	12
Early Summer 1980	22 November - 23 December 1980	18
Mid-Summer 1981	4 January - 28 January 1981	14
Late Summer 1981	4 February - 7 March 1981	20
Autumn 1981	16 March - 6 May 1981	26
Winter 1981	17 May - 9 September 1981	20
Spring 1981	16 September - 18 November 1981	18
Early Summer 1981	25 November - 30 December 1981	8
Mid-Summer 1982	6 January - 30 January 1982	10
Late Summer 1982	3 February - 7 March 1982	14
Autumn 1982	10 March - 5 May 1982	20

associated with the genus *Medicago*.

4.2 METHODS

Information on changes in insect numbers is expressed here in terms of seasonal plant growth periods (Table 4). These are periods in which the lucerne plots at GES went through a complete cycle of plant growth, and were usually terminated by the cutting of the crops. In the mid and late summer 1982 periods, cutting occurred earlier than the last dates shown. Dates for these growth periods were chosen to keep them in synchrony with equivalent periods in 1981.

The three cultivar plots at Ginninderra Experimental Station were along side each other and were managed in the same way including identical times of cutting and spray irrigation. Insecticides were not used during the time of the project. When the crops were cut about 40 mm of stubble was left which then died back and new growth occurred from the crown of the plant at ground level. Cutting does not affect the subsequent regrowth of the foliage and the only apparent change above ground is a broadening of the crown with successive cutting. This is most noticeable in seedlings but less obvious in mature plants.

The main seasonal change in plant growth occurred in winter. Under conditions of low temperature and short day length all three cultivars grew slowly and the stems had internodes of about half the usual length, normal growth resumed in early spring. The 'winter growth periods' were ended when the crops were cut in late September.

A round mouthed net was used for sampling which started only when the stems were above 70 mm in height (Ch 2.5.1). The plots were too small to allow for representative sampling of stubble, so the triangular net was not used.

FIGURE 7. (a) Monthly means of maxima, minima temperatures.
(b) rainfall totals.
Ginninderra Experimental Station.

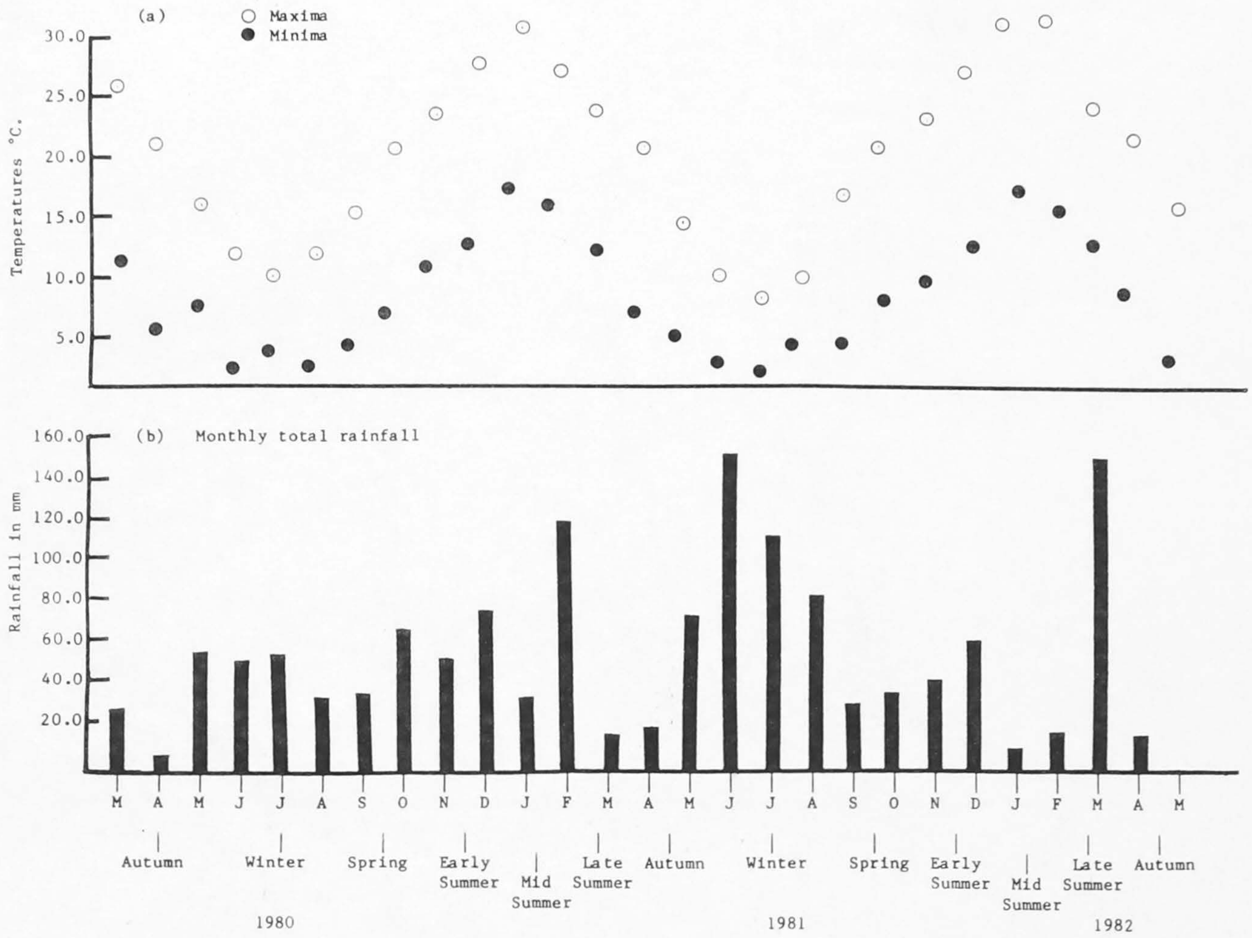
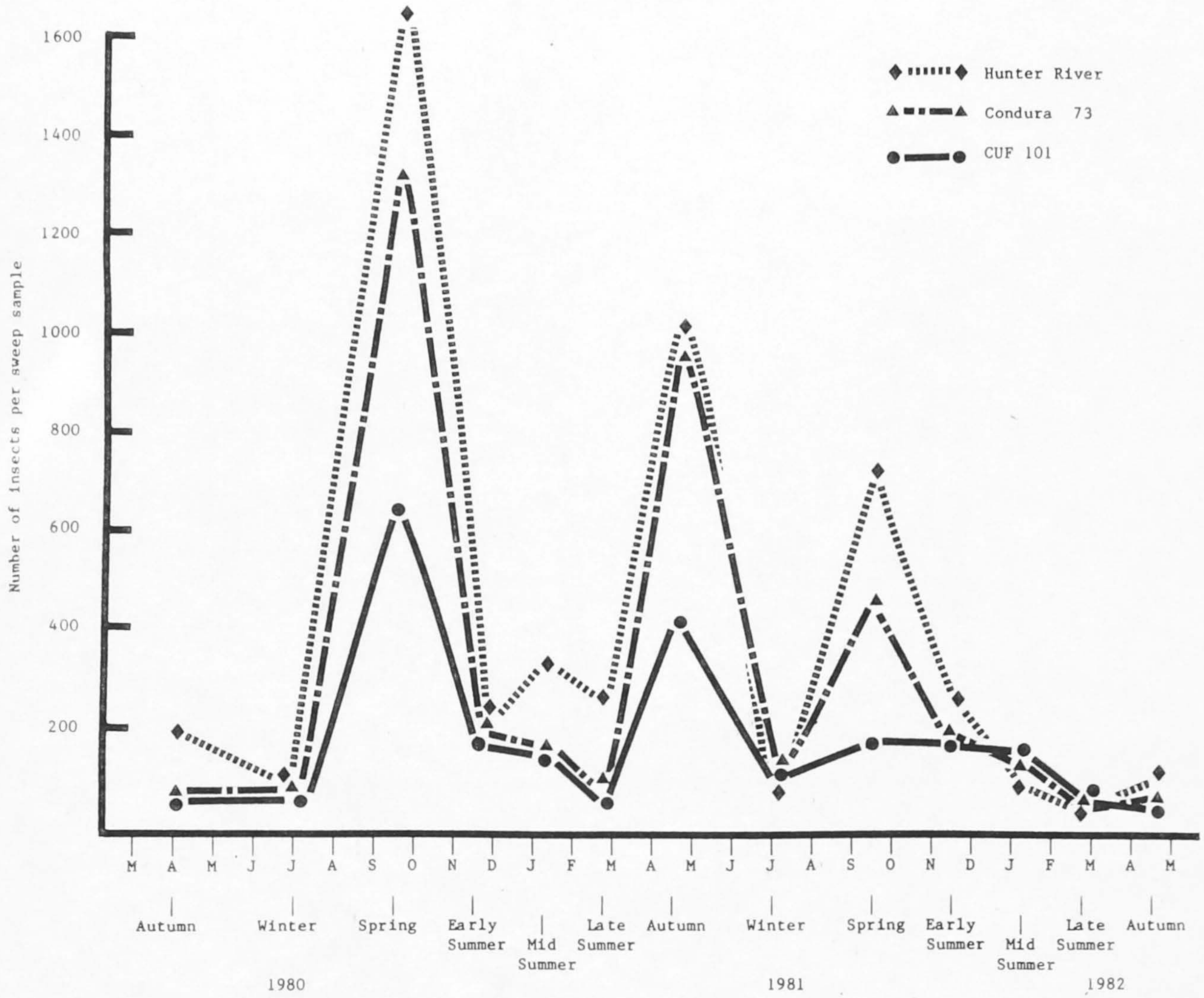
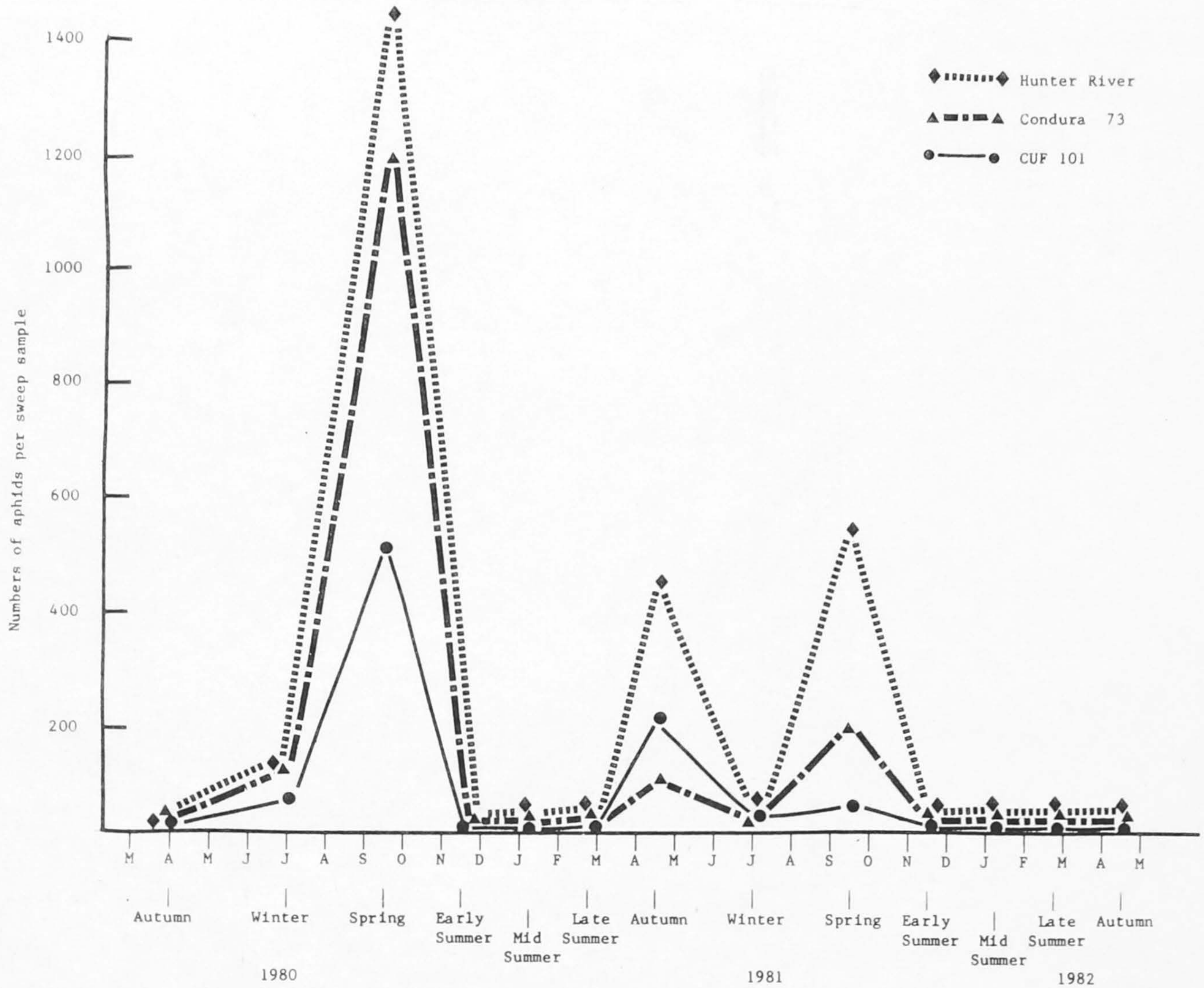

(a)
Maxima
Minima
Temperatures °C.
30.0
25.0
20.0
15.0
10.0
5.0
(b)
Monthly total rainfall
Rainfall in mm
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
M A M J J A S O N D J F M A M J J A S O N D J F M A M
Autumn
Winter
Spring
Early Summer
Mid Summer
Late Summer
Autumn
Winter
Spring
Early Summer
Mid Summer
Late Summer
Autumn
1980
1981
1982

FIGURE 8. Seasonal fluctuations in total insect numbers per sweep sample from three lucerne cultivars. Ginninderra Experimental Station.



Hunter River
Condura 73
CUF 101
Number of insects per sweep sample
1600
1400
1200
1000
800
600
400
200
M A M J J A S O N D J F M A M J J A S O N D J F M A M
Autumn
Winter
Spring
Early Summer
Mid Summer
Late Summer
Autumn
Winter
Spring
Early Summer
Mid Summer
Late Summer
Autumn
1980
1981
1982

FIGURE 9. Seasonal fluctuations in the numbers of Blue-green aphids per sweep sample from three lucerne cultivars. Ginninderra Experimental Station.



Hunter River
Condura 73
CUF 101
Numbers of aphids per sweep sample
1400
1200
1000
800
600
400
200
M A M J J A S O N D J F M A M J J A S O N D J F M A M
Autumn
Winter
Spring
Early Summer
Mid Summer
Late Summer
Autumn
Winter
Spring
Early Summer
Mid Summer
Late Summer
Autumn
1980
1981
1982

FIGURE 10. Seasonal fluctuations in the numbers of Spotted alfalfa aphid per sweep sample from three lucerne cultivars. Ginninderra Experimental Station.

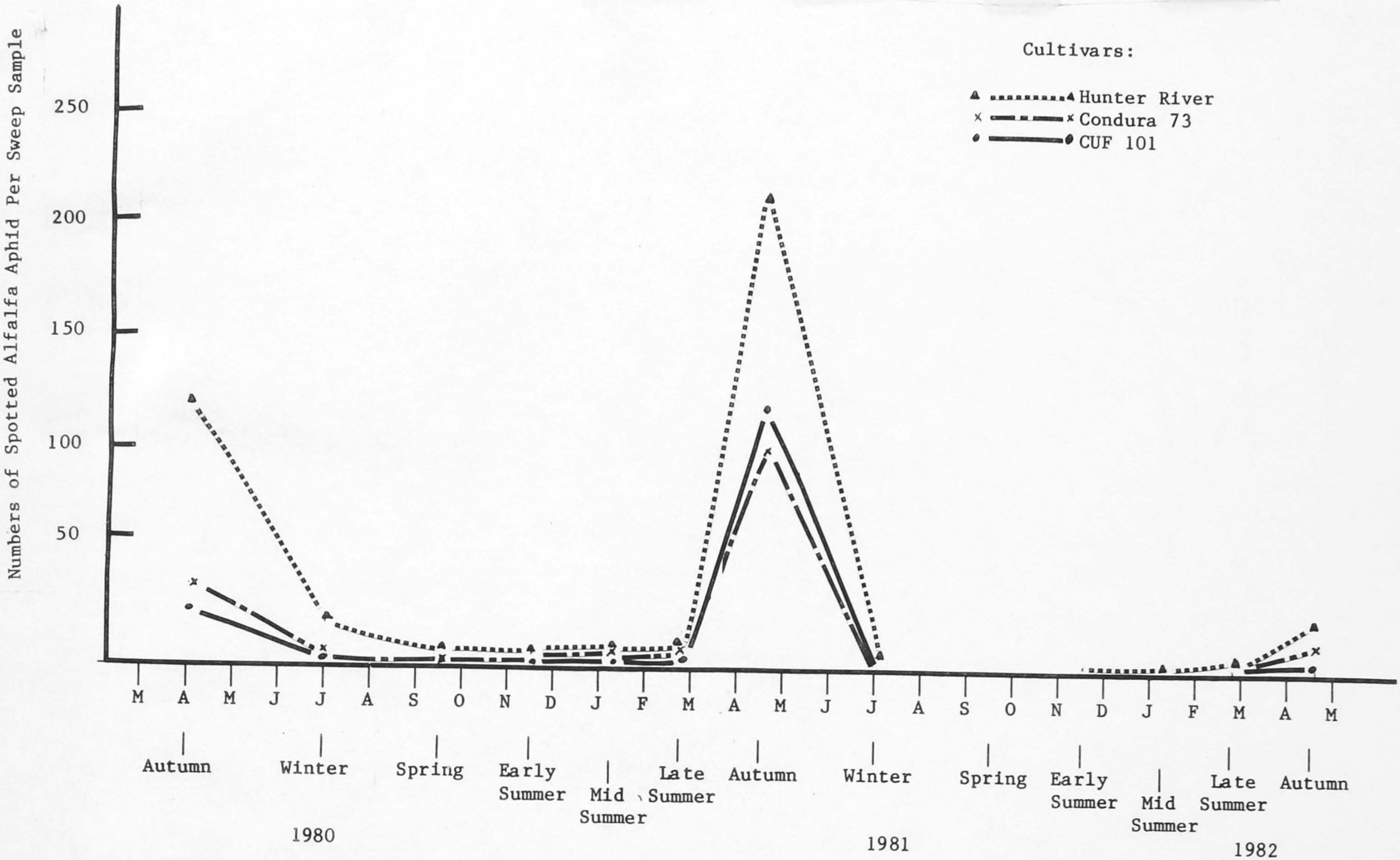
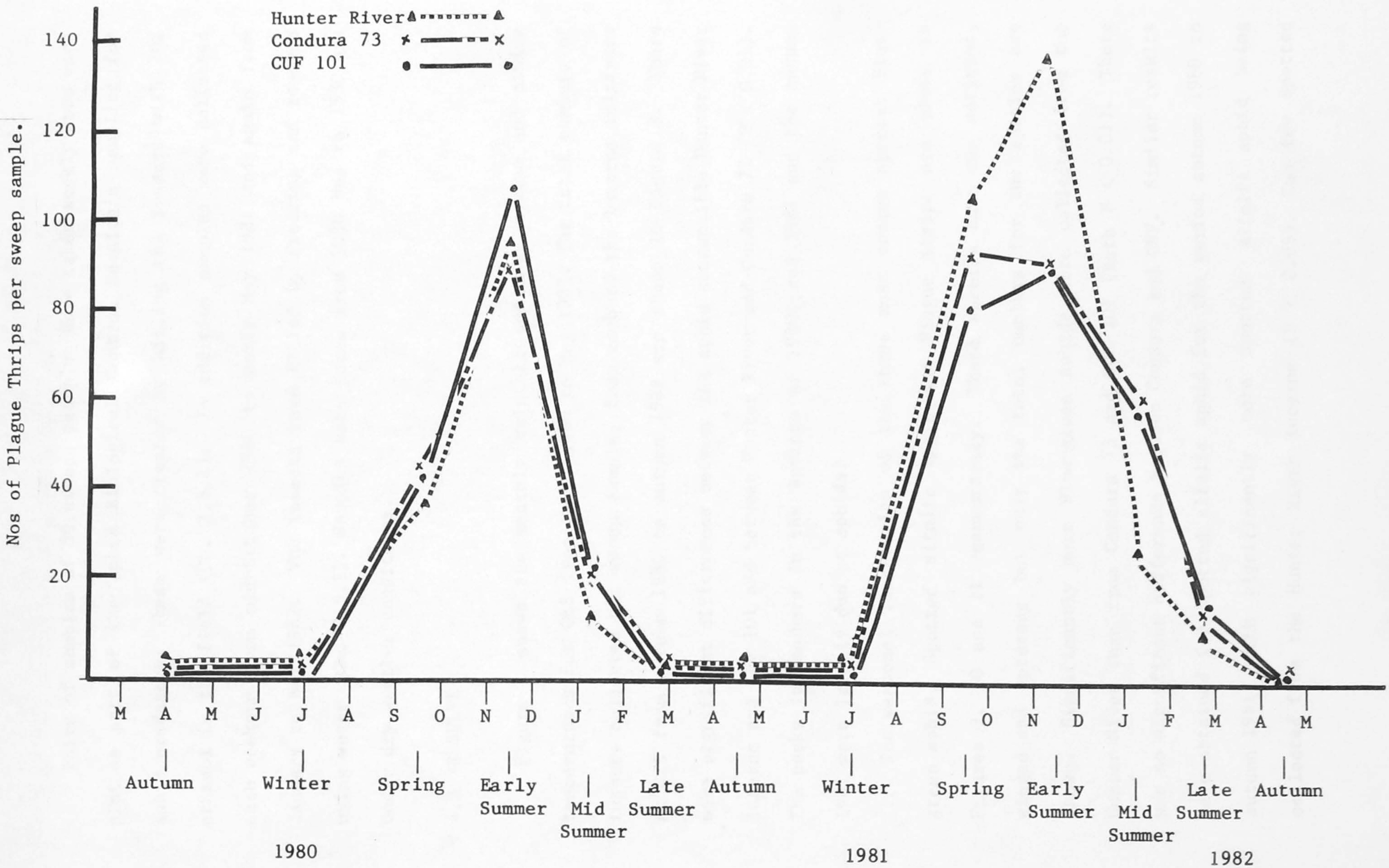

Numbers of Spotted Alfalfa Aphid Per Sweep Sample
250
200
150
100
50
Cultivars:
Hunter River
Condura 73
CUF 101
M A M J J A S O N D J F M A M J J A S O N D J F M A M
Autumn
Winter
Spring
Early Summer
Mid Summer
Late Summer
Autumn
Winter
Spring
Early Summer
Mid Summer
Late Summer
Autumn
1980
1981
1982

FIGURE 11. Seasonal fluctuations in the numbers of Plague thrips per sweep sample from three lucerne cultivars. Ginninderra Experimental Station.


Hunter River
Condura 73
CUF 101
Nos of Plague Thrips per sweep sample.
140
120
100
80
60
40
20
M A M J J A S O N D J F M A M J J A S O N D J F M A M
Autumn
Winter
Spring
Early Summer
Mid Summer
Late Summer
Autumn
Winter
Spring
Early Summer
Mid Summer
Late Summer
Autumn
1980
1981
1982

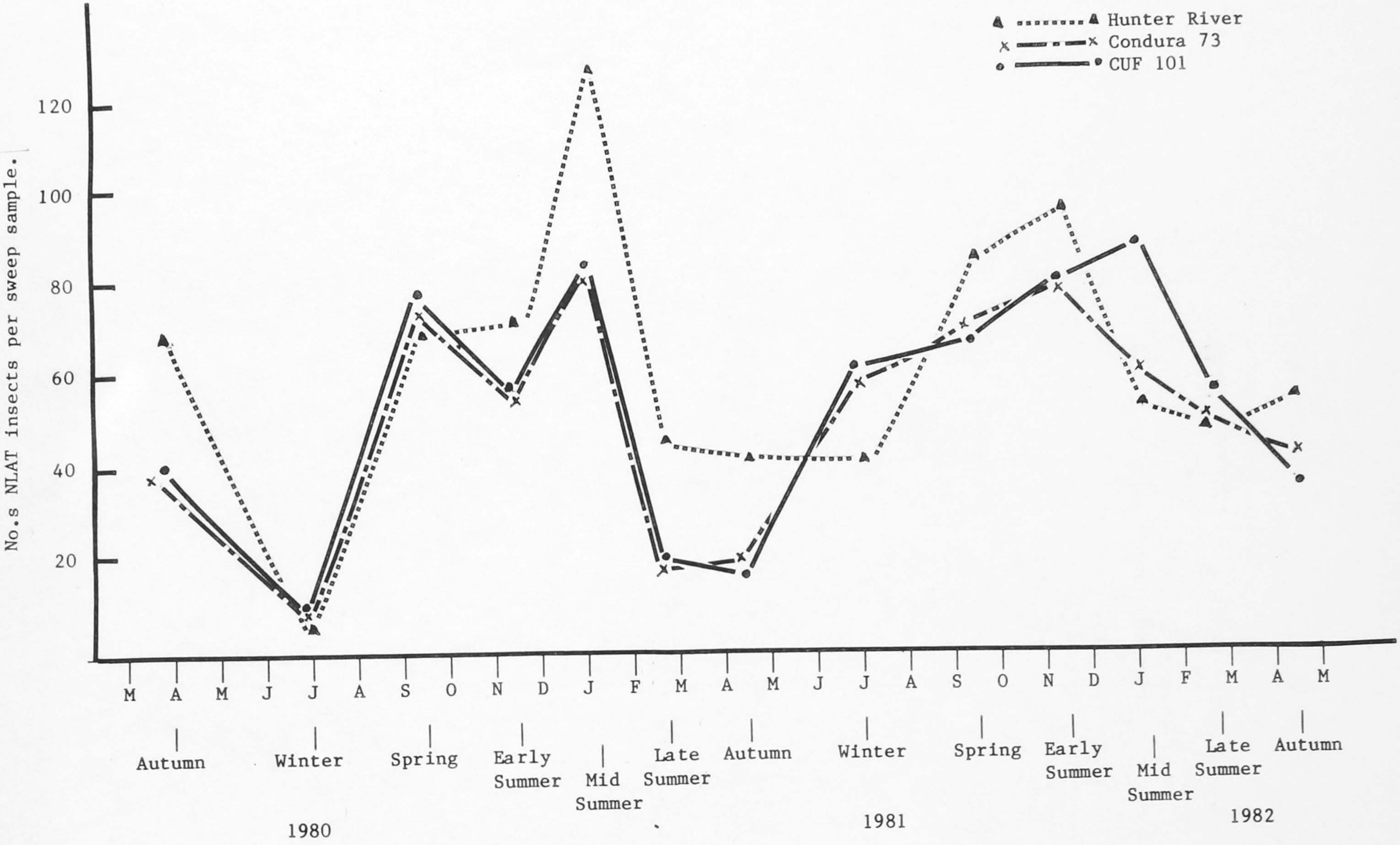
Pairs of samples of 50 sweeps per plot were taken weekly from each plot as part of the Aphid Biological Control Section's sampling for aphid predators. These were treated by killing the insects with 70% ethanol in the field (Ch. 2.5.1). In addition samples were collected each weekend from mid-October 1980 to early May 1981 and again from January to May 1982. The insects were killed by freezing and removed using water (Ch. 2.5.1). Samples were taken from 1030 hrs to 1530 hrs under dry weather conditions.

4.3 RESULTS

Figure 7 shows the monthly rainfall and mean maxima and minima temperatures for GES from March 1980 to May 1982. The total numbers of insects collected per sweep sample, from each of the lucerne cultivars at GES from autumn 1980 to autumn 1982 are shown in Figure 8. There were significant differences between the aphid susceptible Hunter River lucerne and CUF 101 and between Hunter River and Condura 73 ($P < 0.01$). The peaks in numbers in the springs of 1980, and 1981 and the autumn 1981 were largely due to aphids.

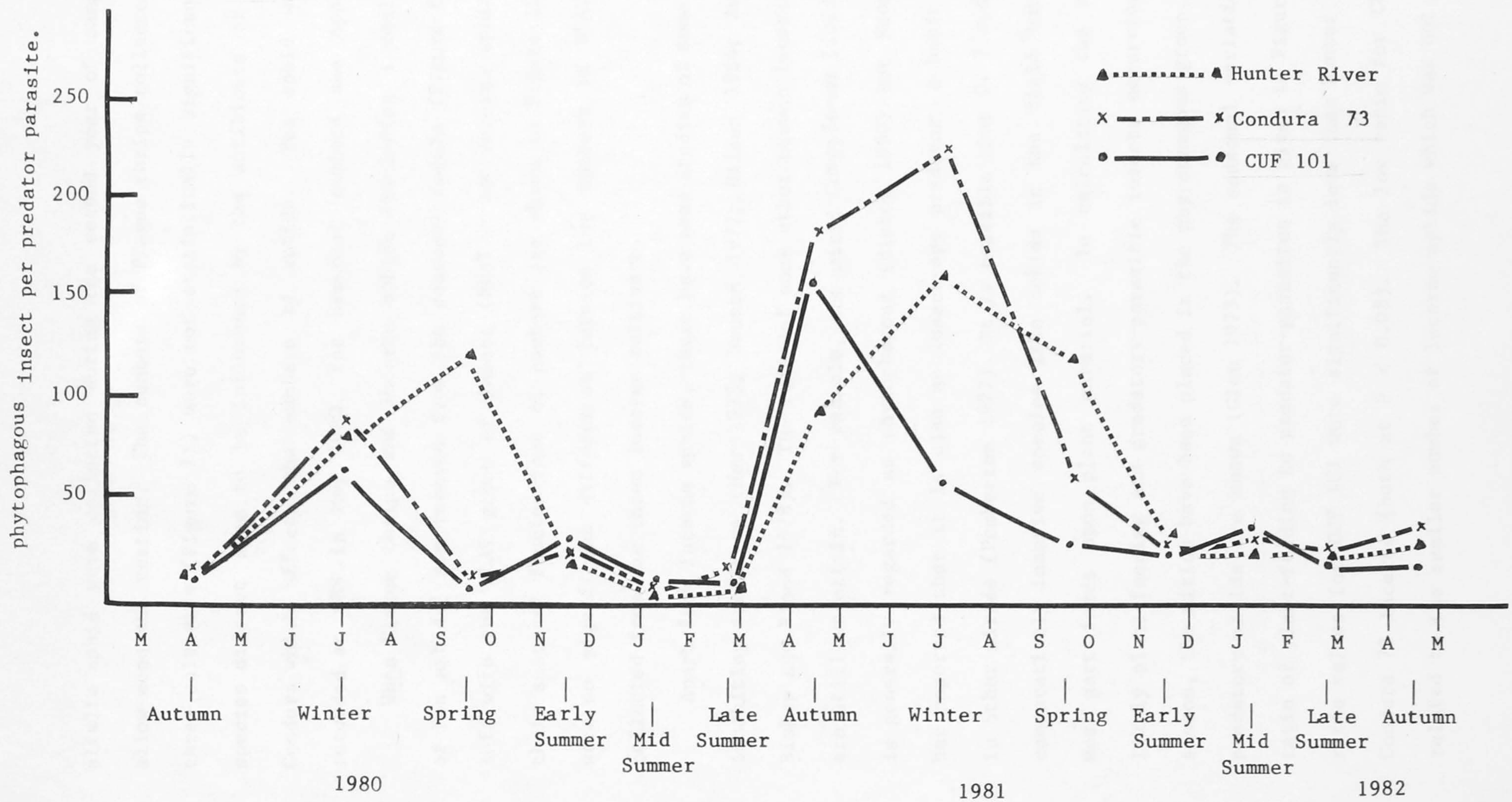
The seasonal fluctuation of the three most common species Blue-green aphid, Spotted alfalfa aphid and Plague thrips are shown in Figures 9, 10 and 11 respectively. These species have two entities, winged and apterous but only the total numbers for the species are shown. Significantly more Blue-green aphids were collected from the Hunter River than from Condura 73 and CUF 101 (both $P < 0.01$). There was no significant difference between Condura and CUF. Similar results were obtained for Spotted alfalfa aphid for the period autumn 1980 to autumn 1981, with significantly more Spotted alfalfa aphid being collected from the Hunter River lucerne ($P < 0.05$). Too few Spotted

FIGURE 12. Seasonal fluctuations in the numbers of non-lucerne aphids and thrips. Ginninderra Experimental Station.



Hunter River
Condura 73
CUF 101
No.s NLAT insects per sweep sample.
120
100
80
60
40
20
M A M J J A S O N D J F M A M J J A S O N D J F M A M
Autumn
Winter
Spring
Early Summer
Mid Summer
Late Summer
Autumn
Winter
Spring
Early Summer
Mid Summer
Late Summer
Autumn
1980
1981
1982

FIGURE 13. Seasonal fluctuations in the ratio of phytophagous insects to predatory parasitic insects in three lucerne cultivars. Ginninderra Experimental Station.



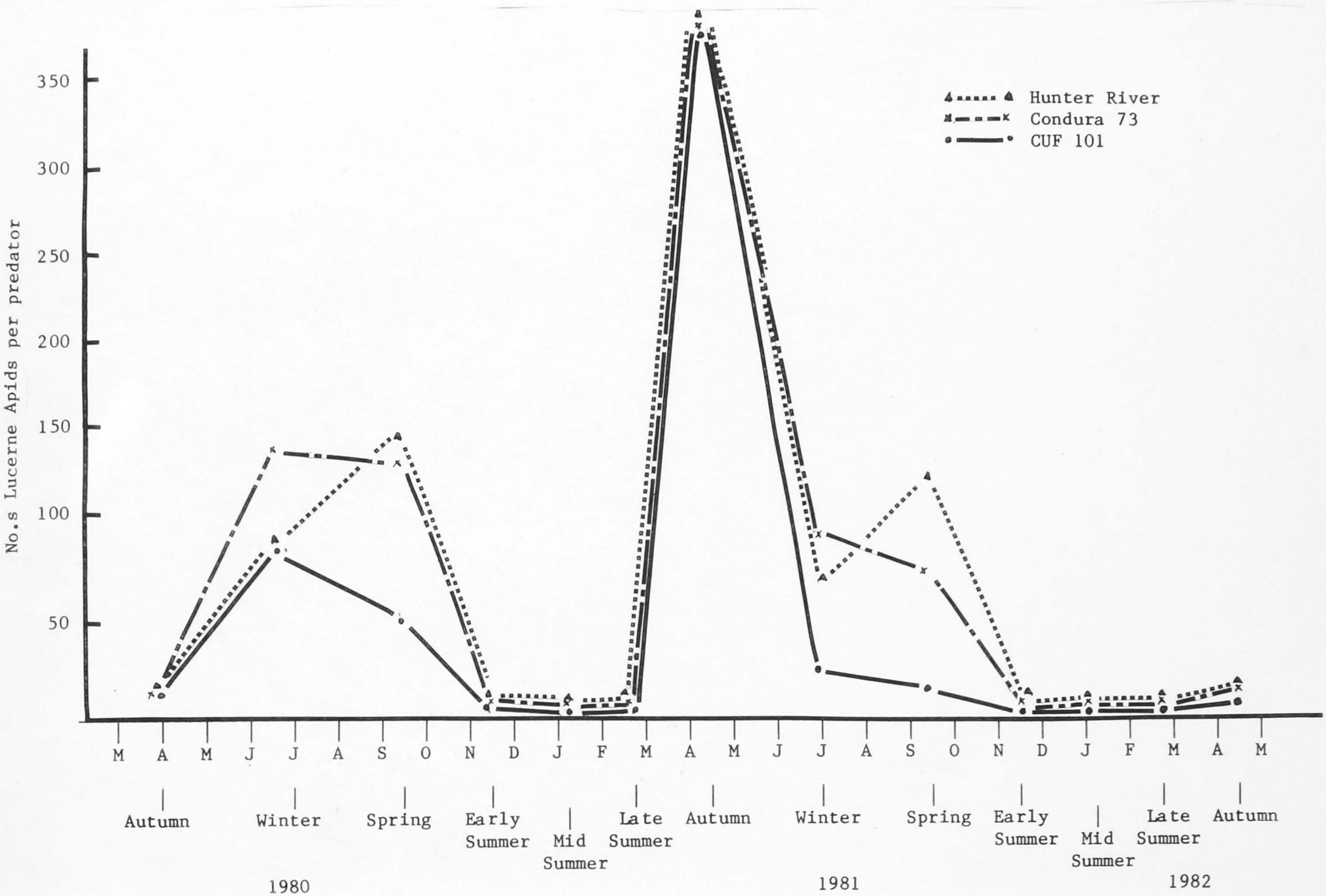
phytophagous insect per predator parasite.
250
200
150
100
50
Hunter River
Condura 73
CUF 101
M A M J J A S O N D J F M A M J J A S O N D J F M A M
Autumn
Winter
Spring
Early Summer
Mid Summer
Late Summer
Autumn
Winter
Spring
Early Summer
Mid Summer
Late Summer
Autumn
1980
1981
1982

alfalfa aphid were collected during the second year of sampling to allow adequate testing. The numbers of Plague thrips collected in the three cultivars (Figure 11) were not statistically significant. This species did not seem to be influenced by the antibiosis of CUF and Condura which affects the numbers of aphids. Pea aphid was first recorded at GES in May 1980, for seasonal numbers see Appendix 1.

When Plague thrips and lucerne aphids (including a small number of Pea aphids) are removed from the seasonal totals (Figure 8) one is left with the NLAT group of insect (NLAT = non-lucerne aphid-thrips) their seasonal fluctuations of numbers are shown in Figure 12. There were no significant differences between the numbers of NLAT insects collected from the three lucerne cultivars.

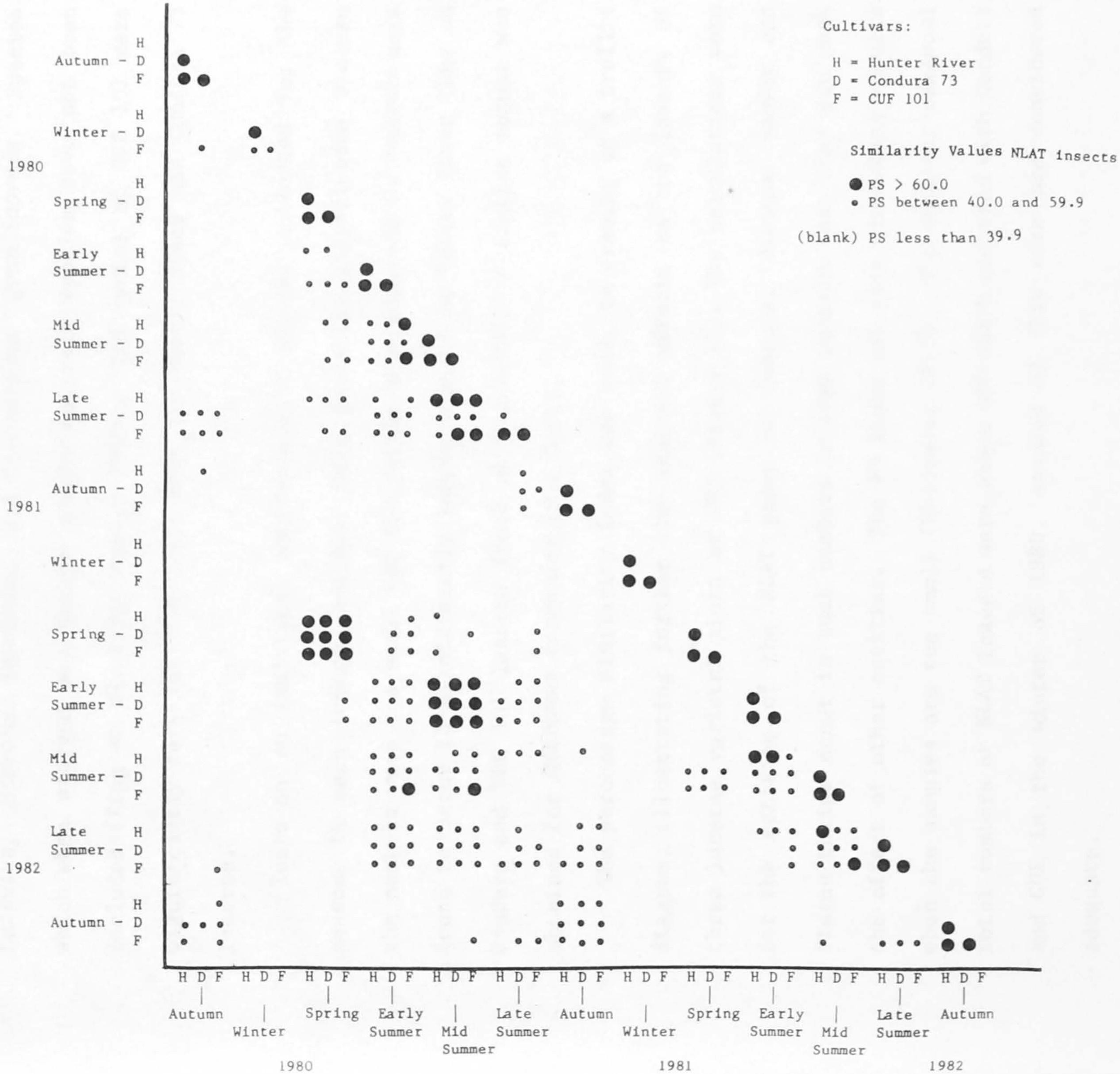
Apart from lucerne aphids, there have been studies of some lucerne-inhabiting predators (New 1975; Samson 1977; Hilson 1964; Awan 1981; Bishop and Blood 1978). The roles of some other common lucerne insects are still uncertain. For example, the mirid *Campylomma livida* Reuter, is generally regarded as phytophagous (Bishop 1980) but Room (1979), has reported that it is also an insect-egg predator, a habit reported in other mirids (Pemberton 1927). It is possible that *C. livida* attacks comparatively inactive species like aphids in the field but for the most part feeds upon plant material. In calculating the number of likely plant-feeding and predatory-parasitic insects occurring in each season, the mirids have been placed in the phytophagous group, although predatory mirids are known (Glen 1973). The seasonal variation of the ratio of plant-feeding to predator-parasites is given in Figure 13. The ratio values for CUF 101 were significantly less than Hunter River and Condura 73 lucerne (both at $P < 0.05$). The low ratio for CUF may be related to the smaller number of lucerne aphids which was not reflected

FIGURE 14. Seasonal fluctuations in ratios of lucerne aphids to predators. Ginninderra Experimental Station.



No.s Lucerne Apids per predator
350
300
250
200
150
100
50
Hunter River
Condura 73
CUF 101
M A M J J A S O N D J F M A M J J A S O N D J F M A M
Autumn
Winter
Spring
Early Summer
Mid Summer
Late Summer
Autumn
Winter
Spring
Early Summer
Mid Summer
Late Summer
Autumn
1980
1981
1982

FIGURE 15. Trellis diagram of PS similarity index values between lucerne cultivars and seasons. Ginninderra Experimental Station. Autumn 1980 to Autumn 1982.



Cultivars:
H = Hunter River
D = Condura 73
F = CUF 101
Similarity Values NLAT insects
PS > 60.0
PS between 40.0 and 59.9
(blank) PS less than 39.9
Autumn
Winter
Spring
Early Summer
Mid Summer
Late Summer
H D F
1980
1981
1982

in a proportional decrease in aphid predators and parasites. Figure 14 shows the seasonal variation in the ratio of lucerne aphids to known aphid predators *Coccinella repanda, Diomus notescens, Dicranolaius bellulus, Micromus tasmaniae* and *Simosyrphus grandicornis*. Species which when starved may attack aphids and rare species have not been included (Ting *et al.* 1978, Ramsay 1963). The ratios of CUF 101 were significantly less (at $P < 0.01$) than for Hunter River and Condura 73 lucerne.

Tests on on individual aphid-predator species collected for the seasons in each lucerne cultivar were generally inconclusive because the numbers were too small but the rather more numerous *C. repanda* were found to occur in significantly larger numbers on Hunter River than on Condura and CUF 101 lucerne (both at $P < 0.05$). A similar result was obtained for *Micromus tasmaniae* ($P < 0.01$).

The percentage similarity index was used, in drawing up a trellis diagram, illustrating further the seasonal effects on the insects of three lucerne varietal plots at GES (Figure 15). The calculations were for the entities of the NLAT group of insects. Lucerne aphids and Plague thrips occur in such numbers in some seasons that they can mask the effect of other entities. The PS index can give misleading results when the samples are too small (Whittaker 1972). The smallest seasonal total numbers of NLAT insects were about 500 which occurred with Condura and CUF in the winter of 1980, samples of this size are considered adequate.

The patterns of PS values for between seasons (Figure 15) are caused by the moderate to high similarity values between seasons spring and autumn (i.e. approximately October to April). The winters of 1980 and 1981 differed from each other in rainfall (Figure 7); during the period May to August 1980 at Ginninderra Experimental Station 192 mm of rain were recorded, in the same months in 1981, despite developing drought conditions over much of eastern Australia, a total of 414 mm were recorded. The Collembola *Katianna australis* was numerous in the wet winter conditions of 1981, and this resulted in the the low PS values between the winters of 1980 and 1981 of about 25.0.

The PS values for different cultivars in the same season, as distinct from samples from different seasons, show an almost uniformally high value. The only exception was in the winter of 1980 when the PS values of CUF x Hunter River and CUF x Condura dropped below 60.0 (Figure 15). The PS index is a reflection of the relative proportion of insect entities in the cultivar samples. The results show that in terms of relative proportions of entities the seasonal effect over-rides any effect of lucerne varieties. If the data from the cultivars are pooled on a seasonal basis and the PS values calculated, the resulting pattern does not differ substantially from that shown in Figure 15.

The seasonal effects of temperature on both insects (Clarke 1967) and lucerne crops (Bolton 1962) are well established. Crop height is affected seasonally as lucerne goes into a dormant state of little or no growth in winter, so that when the plots were cut at GES at the end of autumn they remained low until the start of spring in September. This occurred even in CUF 101 which is supposed to be winter active. Cutting at any time of the year has a major effect on the lucerne insect community (Chapter 5) but in the warmer months the plants re-cover rapidly. Crop height is probably an important factor in the creation of the insect micro-environment through the alteration of the temperature, relative humidity, and living space. This is a complex area of insect plant interaction.

Some initial studies with Hunter River lucerne at Fyshwick gave a simple correlation between mean stem length and log $_e$ (numbers of insects) $r = 0.785$, $df = 13$, $P < 0.01$. The numbers of insects were those collected from sweep samples between November 1979 and February 1980. Mean stem length was estimated from 30 stems selected at random on each of fifteen sampling days. During this period temperatures ranged from a mean maximum of 29.3 to a mean minimum of 13.0°C. The period of sampling corresponded to the early and mid summer seasons of later sampling at Ginninderra.

The relationships between crop height, temperature, insect numbers and season at GES were found to be more complex. Mean day degrees were calculated for each season from autumn 1980 to autumn 1982, by integrating the area under a sine curve, the amplitude of which was set by maximum and minimum temperatures and a predetermined minimum temperature threshold (Allen 1976). Calculations were made using the TEMSUM program with the Csironet Cyber 76 computer. Seasonal mean day degrees were calculated with minimum threshold of 0°, 4°, 8°, and 12°C. A range was used because activity thresholds vary between species, there is no one threshold suitable for the whole community. It was found that there was no correlation between seasonal mean day degrees and total insect numbers (Figure 8) regardless of the minimum temperature threshold used.

When the effect of aphids and Plague thrips were removed the remaining NLAT group had fluctuations in numbers (Figure 12) which followed fairly closely the seasonal trends in temperatures (Figure 7) that is low in winter, high in summer. This trend also occurred with plant height because the lucerne was cut in late autumn and grew very slowly through the winter until September though the crop was cut periodically in the warmer months, the mean plant height was always higher in summer. Consequently over the full year a correlation of plant height and temperature with insect numbers is not valid, because temperature and height are not independent variables.

4.4 DISCUSSION

Lucerne aphids have such an overwhelming effect on the fluctuation of total insects numbers (Figure 8) that it is only when they are excluded from the data that underlying trends become apparent (Figure 12). High insect numbers in summer and low in winter are probably the characteristic pattern for most insect communities in temperate climates that are not subject to summer drought (Pimentel and Wheeler 1973). The low ratio of phytophagous to predatory and parasitic insects in summer (Figures 13 and 14) suggests that for about four months of the year considerable pressure is placed on the plant-feeding insect population.

Gutierrez *et al.* (1980) described how lucerne aphids tended to form colonies around breeding adults. Stem sampling (Chapter 6) suggested that a similar pattern occurred in the crops under study. Gutierrez *et al.* (1980) also determined that predatory ladybird beetles (Coleoptera: Coccinellidae) increased the aggregation of the aphids by differential attacks on colonies, a result of the beetles searching and feeding behaviour. The aphid prey/predator ratio of near unity in summer (Figure 14) suggests that the predators do not feed on aphids for much of the time but may consume other insects.

The absence of any major lucerne varietal effect (Figure 12, 15) on the NLAT insect indicates that the antibiosis bred into CUF and

Condura to combat aphids, does not extend to the whole community. This is consistent with the finding of Pimentel and Wheeler (1973) who obtained similar results from three types of lucerne, two of which had been bred for resistance to Pea aphid. The block like patterns of the percentage similarity values (Figure 15) indicate that through the periods from spring to autumn there is no substantial seasonal change in the composition of the community of NLAT insect but a few species did not follow the general trend. Brown lacewing *Micromus tasmaniae* and the syrphid *Simosyrphus grandicornis* were more plentiful in spring than autumn (Appendix 1), but there was no well defined seasonal succession where one group of species completely replaced another.

The relationship between crop height, temperature and insect numbers is complex and unfortunately the data presented here are not suitable for deeper analysis.

5. EFFECTS OF MANAGEMENT ON LUCERNE INSECTS

5.1 INTRODUCTION

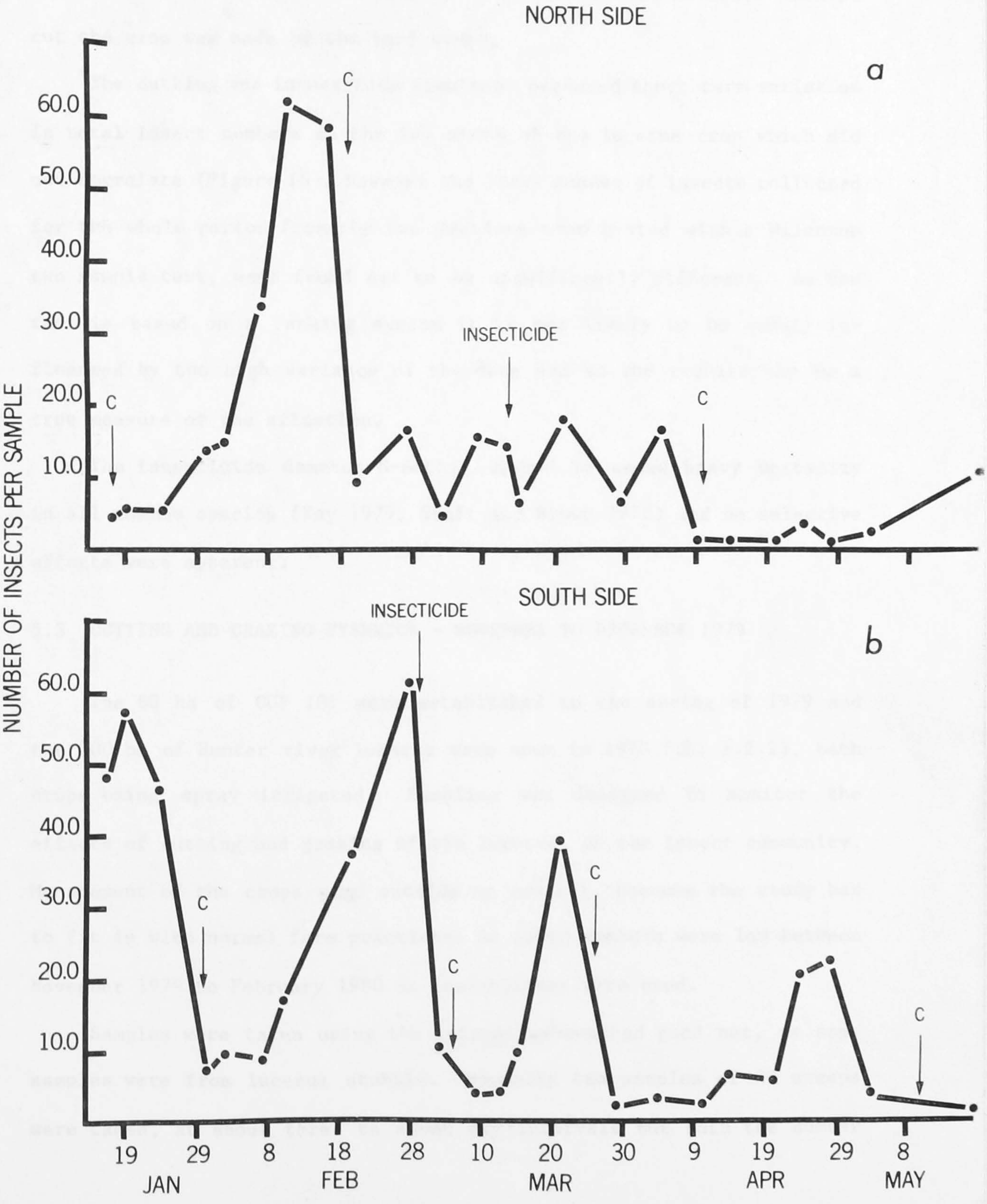
There have been studies on the effects of management practices, such as cutting, grazing and insecticides on individual lucerne insect species and small groups of species but little attention has been given to the insect community (Schlinger and Dietrick 1960, Hughes 1978, Bishop 1978, Bishop *et al.* 1980, Howell and Pienkowski 1971). The aim here is to discuss the effect that the management of lucerne has on the insect community. Crop cutting and grazing has a major but temporary impact on the insects during the warmer months. Only the Fyshwick lucerne was subject to insecticide treatment but the effects were not fully investigated.

5.2 CUTTING AND INSECTICIDE TREATMENT, FYSHWICK - JANUARY TO MAY 1979

The lucerne was cut for fodder as frequently as possible and lucerne aphids were controlled with insecticides. During the initial survey, from January to May 1979, the Hunter River lucerne at Fyshwick was divided into two sections of about 100 ha each (Figure 2, Ch. 1.22). Ten sweep samples of 30 sweeps were taken from each half of the crop on the same sampling day. Samples were taken with the triangular-mouth pond net and placed in plastic bags, frozen and then sorted in large trays (Ch 2.51). These samples were comparable with those from the dryland lucerne and grassland pasture at Kambah which were being taken at the same time (Chapter 3).

In the period 16 January to 8 May 1979 both sides of the crop were cut three times and sprayed with the insecticide demeton-S-methyl once.

FIGURE 16. Fluctuations in the numbers of insects at Fyshwick. Timing of cutting (c) and application of dementon-s-methyl insecticide. January to May 1979.


NORTH SIDE
a
C
C
INSECTICIDE
C
60.0
50.0
40.0
30.0
20.0
10.0
NUMBER OF INSECTS PER SAMPLE
SOUTH SIDE
INSECTICIDE
b
C
C
C
C
60.0
50.0
40.0
30.0
20.0
10.0
19
29
8
18
28
10
20
30
9
19
29
8
JAN
FEB
MAR
APR
MAY

Cutting and insecticide treatment in the two halves of the crop occurred at different times (Figure 16). The time between cutting in the January to April period varied between 25 days: south side 3 March - 28 March to 58 days: north side 20 February - 19 April. The decision when to cut the crop was made by the land owner.

The cutting and insecticide treatment produced short term variation in total insect numbers in the two sides of the lucerne crop which did not correlate (Figure 16). However the total number of insects collected for the whole period from the two sections when tested with a Wilcoxon two sample test, were found not to be significantly different. As the test is based on a ranking system it is not likely to be unduly influenced by the high variance of the data and so the results may be a true measure of the situation.

The insecticide demeton-S-methyl seemed to cause heavy mortality in all common species (Kay 1979, Croft and Brown 1975) and no selective effects were apparent.

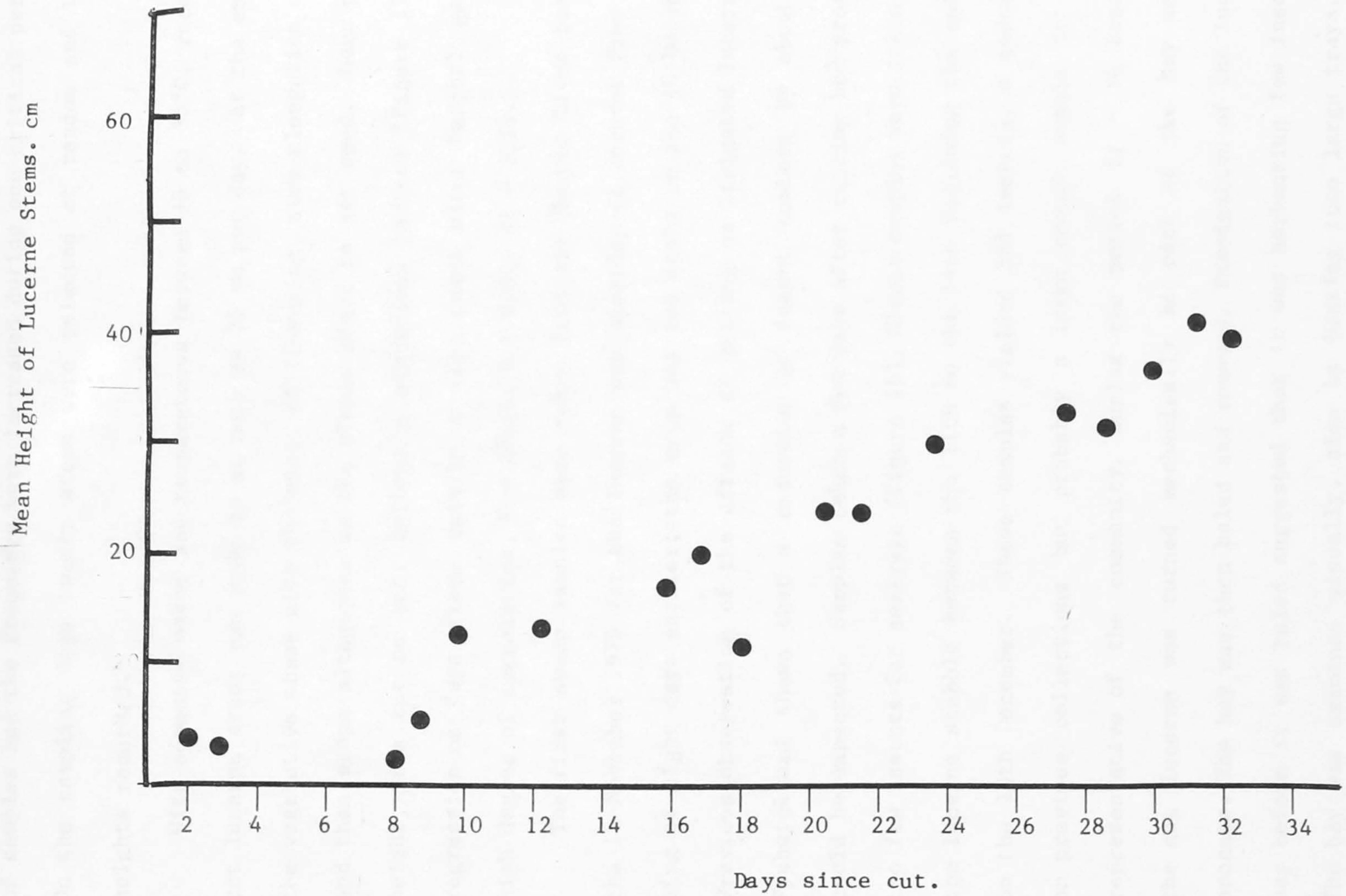
5.3 CUTTING AND GRAZING FYSHWICK - NOVEMBER TO DECEMBER 1979

The 60 ha of CUF 101 were established in the spring of 1979 and the 200 ha of Hunter river lucerne were sown in 1978 (Ch. 1.2.2), both crops being spray irrigated. Sampling was designed to monitor the effects of cutting and grazing of the lucerne, on the insect community. Management of the crops was outside my control, because the study had to fit in with normal farm practices. As aphid numbers were low between November 1979 to February 1980 no insecticides were used.

Samples were taken using the triangular-mouthed pond net, as some samples were from lucerne stubble. Normally ten samples of 30 sweeps were taken, at about three to seven day intervals but both the number

60

FIGURE 17. Growth of Hunter River lucerne. Fyshwick.
Means of 30 stem measured *in situ*.



Mean Height of Lucerne Stems. cm
60
40
20
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
Days since cut.

of samples and the frequency were increased during one critical period. On the sampling days twenty stems were selected at random and their heights recorded.

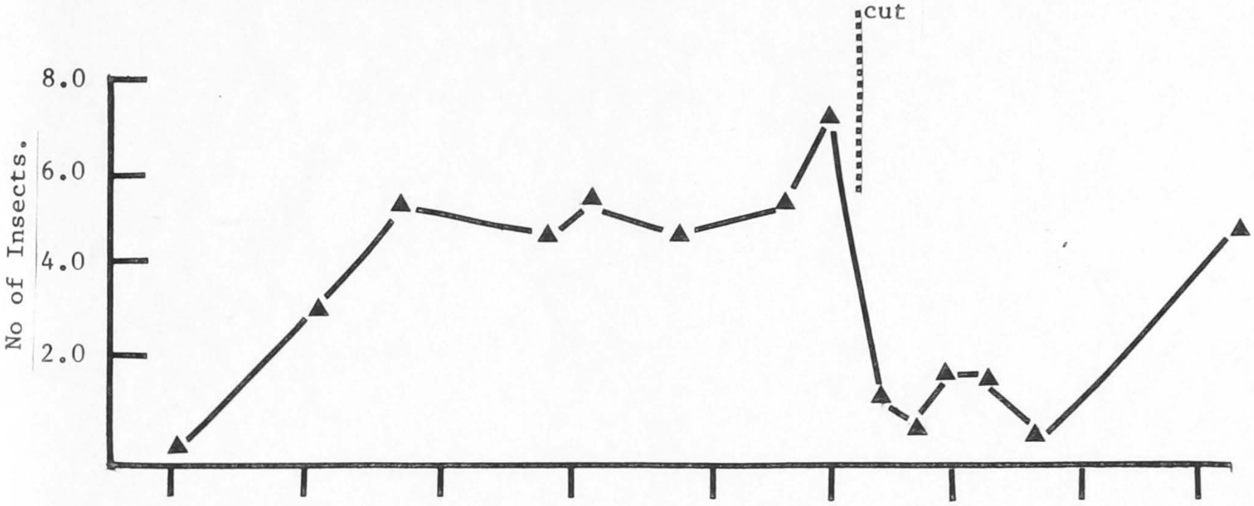
With adequate water and temperatures between 15 to 35°C, recently cut lucerne stems can grow by as much as 25 mm per day. At the end of the vegetative phase with the onset of flowering, stem elongation slows and then stops altogether as the plants start to set seed. Mean plant height, from cut to cut, follows a sinusoidal pattern (Figure 17). A regression of days since cutting x sine (mean plant height) gave a high degree of correlation, $F = 293.4$, $P < 0.01$, $df = 1,15$.

The first sweep samples were taken from the Hunter River crop on the 15 November 1979 for the lucerne was starting to recover from cutting of eight days earlier; the crop was cut again on the 10 December. Previous observation of the effects of cutting on irrigated lucerne at Fyshwick had shown that a reduction of insect numbers by about 95% could be expected. Samples taken a few days after cutting had provided too few insects for analysis (Figure 16). Ninety samples were taken from the lucerne stubble between the 11th to the 14th following the cutting on the 10th December. These samples yielded 584 insects, a reduction on previous collections but probably a large enough sample to be a representative of the community. During the period 11 - 14 December the cut lucerne was turned mechanically as part of the hay making process. The hay was then baled and removed. Examination of the lucerne hay before it was baled suggested that it was harbouring few insects. The hay was examined visually, also by beating into large trays. In addition, sweep samples were taken from the stubble just after the hay had been rolled away as part of the drying process, the results also suggested that the hay was not harbouring large numbers of insects.

FIGURE 18. Affects of cutting Hunter River lucerne on the numbers of insects. Fyshwick. November-December 1979.

(a) predatory and parasitic insects
(b) phytophagous insects.

(a) Predatory and Parasitic insects



(b) Phytophagous insects

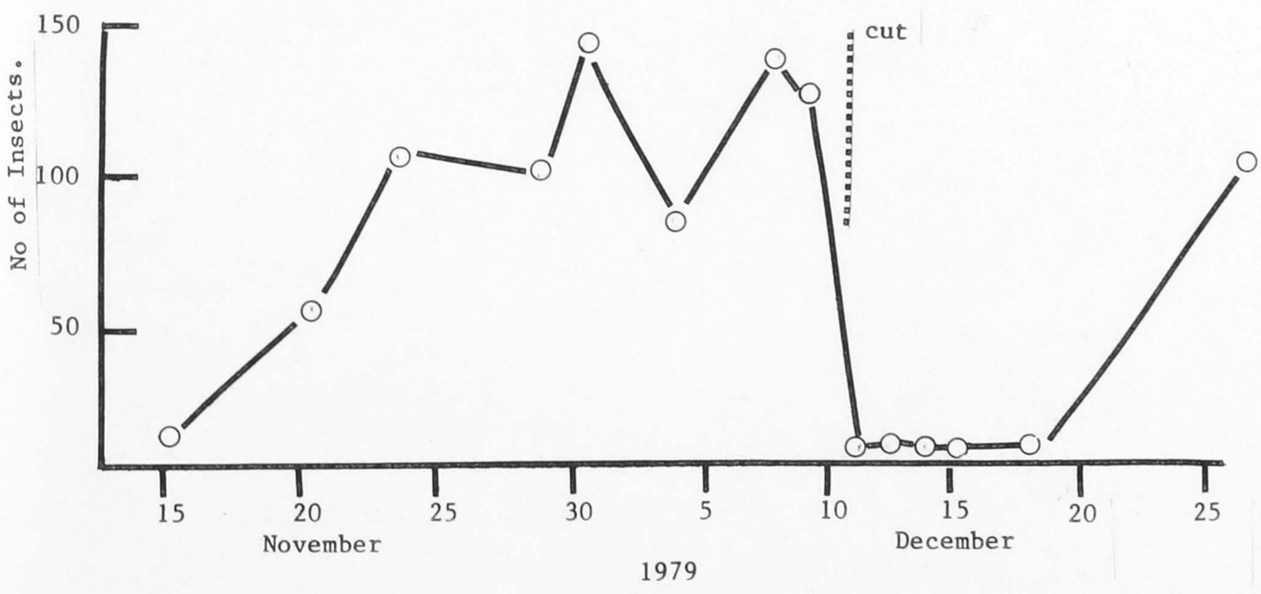
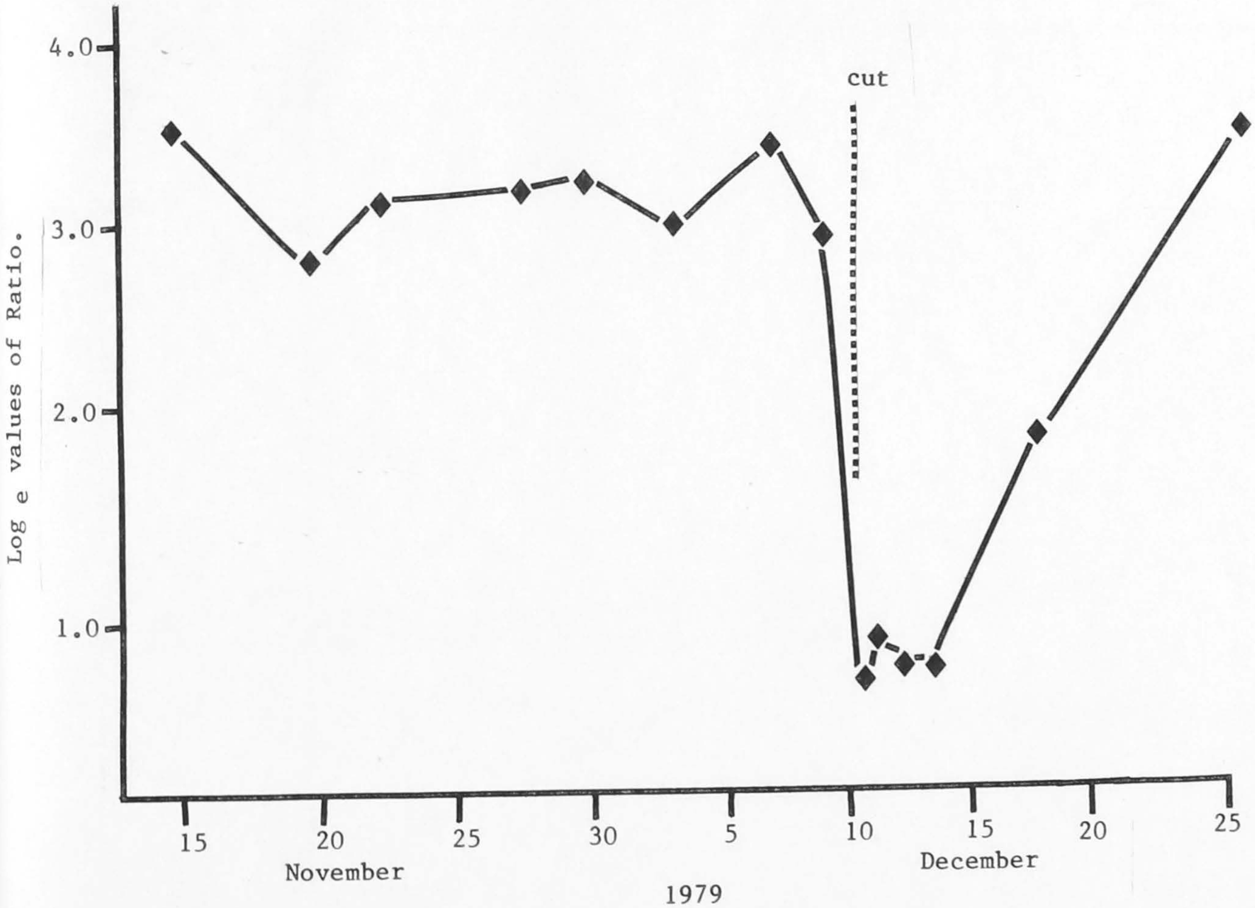
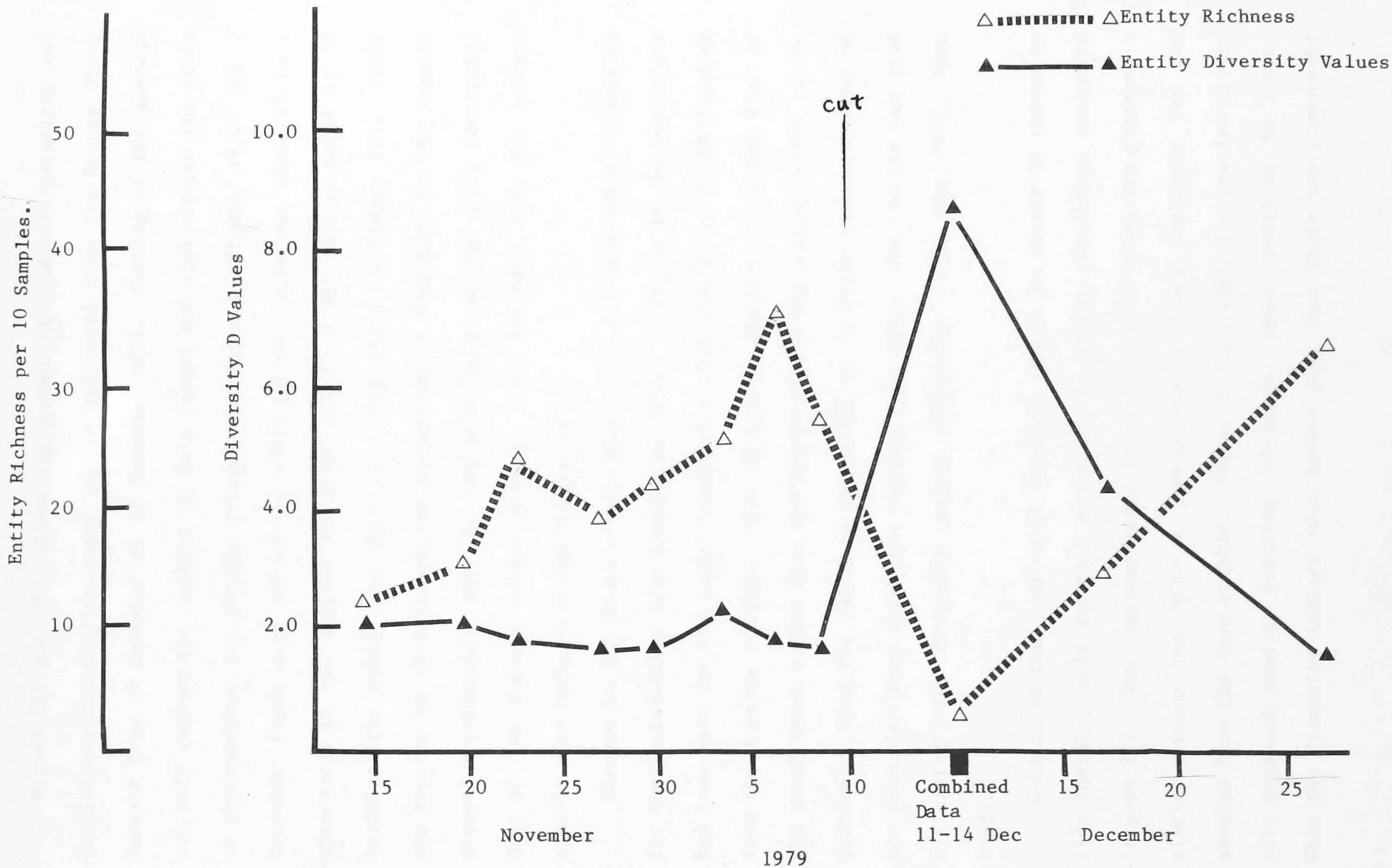


FIGURE 19. Log_e Ratios of phytophagous/predatory parasites. Hunter River lucerne. Fyshwick. November - December 1979.



4.0
3.0
2.0
1.0
Log e values of Ratio.
cut
15
20
25
30
5
10
15
20
25
November
December
1979

FIGURE 20. Affects of cutting Hunter River lucerne on richness and diversity. Fyshwick. November - December 1979.



Entity Richness
Entity Diversity Values
cut
Entity Richness per 10 Samples.
50
40
30
20
10
Diversity D Values
10.0
8.0
6.0
4.0
2.0
15
20
25
30
5
10
Combined Data 11-14 Dec
15
20
25
November
December
1979

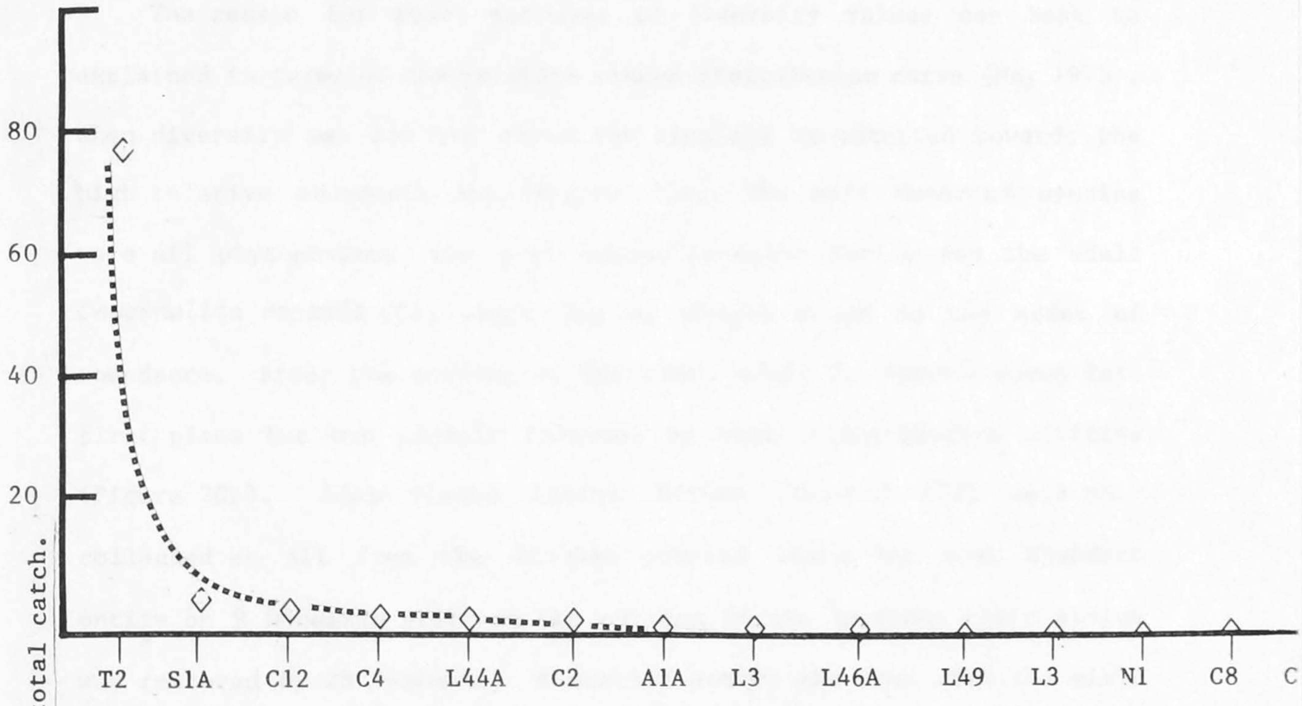
Figure 18a and 18b, shows the number of predators/parasites and herbivorous insects per sweep sample collected from the Hunter River lucerne from 15 November to 28 December 1979. Cutting of the lucerne not only reduced the numbers of both groups but also altered the ratio of phytophagous to predatory-parasitic insects (Figure 19). On 7 December, three days before the cutting, the ratio was about 27 to 1 afterwards it had dropped to about 2.5 to 1 but was restored by 28 December (the ratios are shown on a log scale in Figure 19). After the cutting on 10 December the proportion of Hemiptera in the samples dropped considerably only to increase again as the crop recovered. Most of the insects caught between 11-14 December from the lucerne stubble were Orthoptera and Coleoptera.

Changes in the Simpson-Yule index (Ch. 2.3) for entity diversity for the Hunter River crop samples are shown in Figure 20. No adjustment has been made for the large number of pooled samples of 11-14 December from the lucerne stubble. With diversity indices it is the size of the total catch rather than the degree of pooling samples which can be critical. When the catch is too small to be truly representative of the community from which the samples were taken, the results can give misleadingly low diversity values (Whittaker 1972, May 1975, Peet 1975).

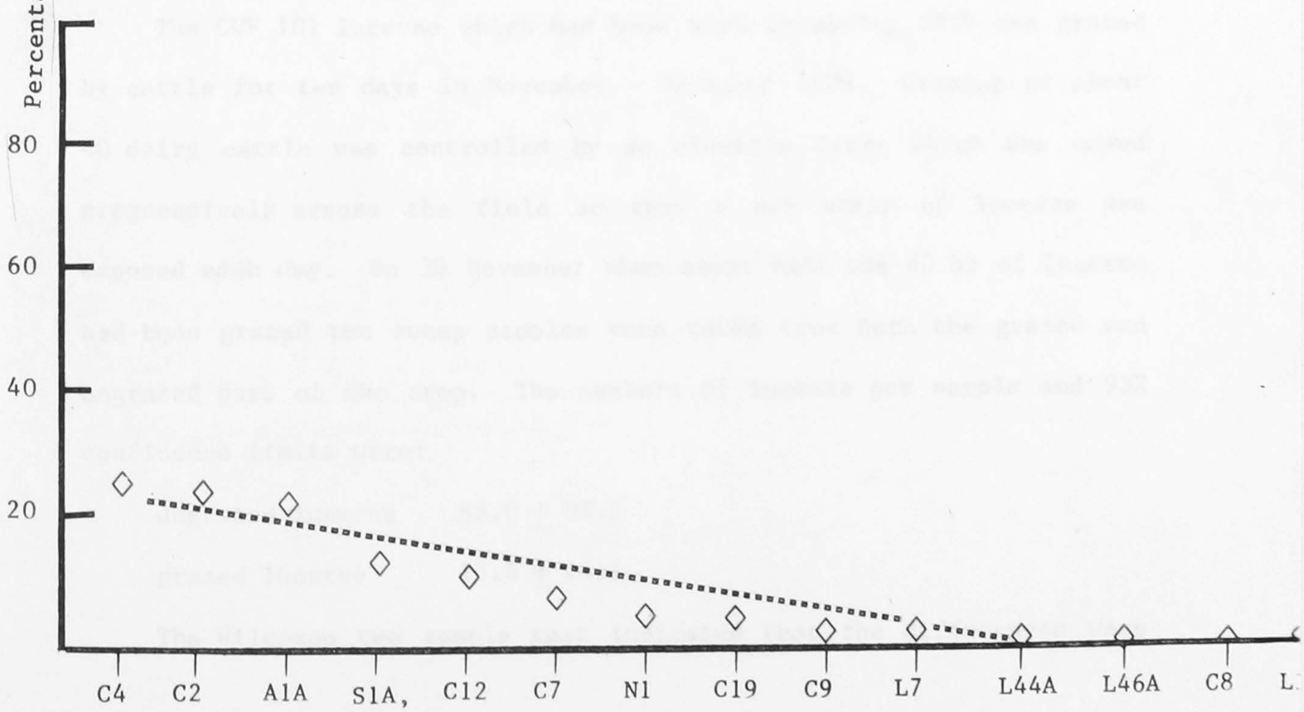
Cutting of the crop on 10 December caused the diversity values to rise sharply, only to fall again as the insect population recovered (Figure 20). The Shannon-Weaver index for entity diversity produced a similar pattern but with a proportionally lower amplitude for the samples from the crop stubble. Values of this index for species diversity produced similar patterns, although values tended to be lower. When the diversity indices were broken down into their two components

FIGURE 21. Rank distribution: proportion of the most numerous insect entities as a percentage of the total catch (a) before; (b) after lucerne was cut on 10 December 1979. Hunter River lucerne. Fyshwick. The lines were fitted by eye.

(a) 9 December before crop was cut, total catch 1296.



(b) 11 - 14 December after crop was cut, total catch 584.



of richness and evenness (Tramer 1969) it was found that they were negatively correlated ($P < 0.05$). Evenness of entities rose sharply after cutting while those for richness fell (Figure 20).

The reason for these patterns of diversity values can best be explained in terms of the relative ranked distribution curve (May 1975). When diversity was low the curve was strongly accentuated towards the high relative abundance end (Figure 21a). The most numerous species were all phytophagous, the most common predator entity was the adult *Coccinellia repanda* (C4) which lay at fourth place in the order of abundance. After the cutting of the crop, adult *C. repanda* moved into first place but was closely followed by three plant-feeding entities (Figure 20b). Adult Plague thrips *Thrips imaginis* (T2) were not collected at all from the stubble despite being the most abundant entity on 9 December prior to the cutting of the lucerne, their status was restored by 28 December. A similar pattern was seen with the mirid *Campylomma livida* (L49). Entities C9, C19, L7, L3 (see Table 2) were present in the crop prior to cutting (Figure 21b).

The CUF 101 lucerne which had been sown in spring 1979 was grazed by cattle for ten days in November - December 1979. Grazing of about 40 dairy cattle was controlled by an electric fence which was moved progressively across the field so that a new strip of lucerne was exposed each day. On 30 November when about half the 60 ha of lucerne had been grazed ten sweep samples were taken from both the grazed and ungrazed part of the crop. The numbers of insects per sample and 95% confidence limits were:

ungrazed lucerne	88.0 ± 32.6
grazed lucerne	13.6 ± 14.1

The Wilcoxon two sample test indicated that the differences were

TABLE 5. INSECTS PER SWEEP SAMPLE: PREY/PREDATOR RATIOS - FYSHWICK - NOVEMBER TO DECEMBER 1979

Numbers of insects per sweep samples Fyshwick 15 November to 28 December 1979 PHYT = phytophagous insect; PRED = predator and parasitic insects; RATIO = PHYT/PRED.

	HUNTER RIVER				CUF 101		
	PHYT	PRED	RATIO		PHYT	PRED	RATIO
DATE							
15 Nov	10.4	0.3	34.6		7.7	1.4	5.5
20 Nov	64.2	3.5	18.4		29.1	3.7	7.8
13 Nov	126.6	5.1	24.8		252.0	2.0	126.0
28 Nov	107.2	4.2	25.5		61.2	4.6	13.3
30 Nov	151.7	5.0	30.3	Ungrazed	77.6	9.8	7.9
30 Nov				Grazed	12.3	1.2	10.2
4 Dec	76.5	4.7	16.3		1.6	0.1	16.0
7 Dec	131.3	5.3	24.8		8.5	0.3	28.3
9 Dec	121.1	7.3	16.6		-	-	-
10 Dec	HR CUT						
11 Dec	6.4	1.7	3.8		-	-	-
12 Dec	4.5	1.3	3.5		39.3	2.0	19.6
13 Dec	3.2	1.0	3.2		-	-	-
14 Dec	4.5	2.2	2.0		45.4	2.1	21.6
18 Dec	4.3	0.7	6.1		100.7	2.3	43.8
28 Dec	109.2	5.5	19.8		140.9	8.1	17.4

significant (Us = 99, $P < 0.01$). The ratios of phytophagous to predator-parasites were: ungrazed 7.9 to 1 and grazed 10.1 to 1. Unlike the Hunter River lucerne when the top growth was removed there was no significant change in the ratio. Adult Plague thrips were the most abundant entity in the samples from both grazed and ungrazed sections of the CUF lucerne. In the Hunter River lucerne no thrips were collected from the stubble following cutting.

Sweep samples were again taken on 4 December, after grazing was completed and any tall weeds left by the cattle had been mechanically mowed to a uniform height at about 40 mm. Ten samples were taken, the number of insects was 1.7 per sample indicating that insect numbers had continued to decline after grazing was completed. Table 5 shows the mean number of herbivorous and predatory-parasitic insects collected each sampling day from the two lucerne crops at Fyshwick.

5.4 RECOLONIZATION OF LUCERNE CROPS AFTER CUTTING

Once the new shoots have started to develop rapidly at the base of the lucerne plant after cutting, insect numbers start to increase again. Some of the recolonization is probably due to immigration; Blue-green aphids and Spotted alfalfa aphids are commonly caught in yellow water traps (Berg and Ridland 1978). Other arthropods have well developed mechanisms for dispersal (Bristowe 1929, Price 1976) but there may be important refuges in or about the lucerne fields; these would include field verges and adjacent crops.

It was noticed that after cutting and harvesting, scattered upright stems of lucerne remained. These stems ranged from 3 per m^2 to 1 per 10 m^2 depending on the efficiency of the machine used to cut the crop. Lodging can be a problem in crops like wheat but is not usually so pronounced in lucerne although when it does occur, the efficiency of mechanical cutting may be reduced. Examination of stems left after harvesting showed that although they suffered some damage, (usually their tops were missing) they often harboured insects, particularly aphids and thrips.

Another source of colonizing insects are weeds in or about the lucerne crop. All non-lucerne plants species are considered to be weeds but the clovers and grasses form an important part of lucerne hay even though they may be self-introduced. Speight and Lawton (1976) found that weed species were important in the ecology of some ground beetles (Carabidae and Staphylinidae) in cereal crops. Lucerne aphids and thrips are known to occur on other medics and clovers (Lodge and Greenup 1978). Sweep samples from areas of clover at Fyshwick in December 1979 indicated a high thrips population. Some aspects of recolonization were investigated further with a series of small plot experiments.

5.4.1 Weed removal: small plots Fyshwick

On 2 December 1979 ten plots 2 m^2 were marked with wooden pegs in the Hunter River lucerne at Fyshwick. There was no restriction on the movement of insects other than the wooden pegs at the corners of each plot. In five of the plots all weeds were removed by cutting the vegetation at ground level, the soil and the lucerne was left undisturbed. The plots were then examined every two days and weed regrowth was removed. On 9 December 1 m^2 at the centre of the plots were sampled with a Burkard suction-sampling machine. In each plot, the heights of six randomly selected lucerne stems were measured.

The experiment was repeated in the CUF 101 crop at Fyshwick, with the number of plots increased to 10 per treatment. The plots were

TABLE 6. WEED REMOVAL - SMALL PLOTS AT FYSHWICK. INSECT PER MACHINE SUCTION SAMPLE.

In the first experiment there were five plots per treatment each plot being 2 m^2.
In the second experiment treatments were increased to ten plots each.

FIRST PLOT EXPERIMENT : HUNTER RIVER

TREATMENT	HEIGHT OF LUCERNE MEANS ± S D IN CM	NO OF INSECTS PER SUCTION SAMPLE
ALL WEEDS REMOVED	39.5 ± 9.9	6.6 ± 2.1
CONTROL	39.5 ± 11.0	10.0 ± 5.2

SECOND PLOT EXPERIMENT : CUF 101

TREATMENT	HEIGHT OF LUCERNE MEANS ± S D IN CM	NO OF INSECTS PER SUCTION SAMPLE
WEEDS REMOVED (THROUGHOUT SAMPLING PERIOD)	48.0 ± 9.4	8.6 ± 2.1
WEEDS REMOVED ONCE ONLY	46.6 ± 10.0	10.9 ± 3.2
CONTROL	50.1 ± 9.6	9.3 ± 3.3

TABLE 7. SMALL PLOT - LAKE GINNINDERRA DRYLAND LUCERNE

Ten plots of 1 m^2 were cut on 18 October 1981 with a further ten plots being left as uncut controls. *In situ* stem samples taken on 25 October, most of the insects were Blue-green apid.

Mean stem lengths are calculated from 30 stems, in the cut and control plots.

The insects were counted *in situ* three stems from each cut plot and control plots.

	STEM MEAN LENGTH AND STANDARD DEVIATION IN CM (OF 30 STEMS)	TOTAL INSECTS 30 STEM SAMPLE	INSECTS PER 100 mm OF STEM
CUT PLOT	6.6 $\pm$ 2.3	247	124.7
UNCUT	41.4 $\pm$ 13.6	254	20.4

TABLE 8. CUT PLOT EXPERIMENT - GINNINDERRA EXPERIMENTAL STATION (GES)

Ten small plots cut into each cultivar on 12 April 1982. Three stems were taken from each plot and three from the lucerne adjacent to each plot on 24 April. Thirty plant stem samples were taken from each treatment.

LUCERNE CULTIVAR		NO OF LEAVES	TOTAL INSECTS	INSECTS PER TEN LEAVES	MEAN PLANT HEIGHT ± SD IN CM
Hunter River	Uncut	1078	468	4.26	42.4 ± 9.2
	Cut	119	106	8.91	4.5 ± 2.4
Condura 73	Uncut	893	23	0.25	42.6 ± 12.5
	Cut	142	33	2.30	6.4 ± 2.8
CUF 101	Uncut	895	13	0.14	48.7 ± 12.9
	Cut	181	17	0.90	11.2 ± 4.4

marked out on 1 January 1980 and sampled on 9 January. Besides the controls there were two other types of treatment; in one group weeds were removed from the plots every two days as before, in the other weeds were removed at the start but were not further suppressed. The results are shown in Table 6, there were no significant differences between the numbers of insects in any of the plots.

5.4.2 Small plot cutting experiments at Ginninderra

Two small plot trials were conducted in the Ginninderra area when there were large numbers of aphids in the lucerne. The first of these was in the "Hunter River" dryland crop at Lake Ginninderra. Ten 1 m^2 plots were cut in the crop of lucerne on 18 October 1981. Cutting was done with garden shears and the pattern was similar to that produced by mechanical harvesting with all the top growth being removed above 30 mm, so that all new shoots of lucerne would arise from the crown at ground level. Seven days later 30 stems were sampled for insects from the plants and an equal number were made from the surrounding uncut lucerne. The *in situ* sampling method was used, where the insects are counted on the plant in the field (Ch. 2.5.2). The mean length of stem, total insects and numbers per 100 mm of stem are shown in Table 7.

The second small plot experiment was at GES in the autumn of 1982. Ten plots covering 1 m of row were cut into the three cultivars on 12 April. Methods of cutting were the same as for the plots at Lake Ginninderra. From each cultivar thirty stems were taken from the plots and thirty from the surrounding uncut lucerne. Samples were made twelve days after cutting. At this time the uncut lucerne had lost most of its leaves from the lower part of the stem so the numbers of insects are expressed as insects per 10 leaves (Table 8) most insects were Blue-green aphid and Spotted alfalfa aphid. Wilcoxon two sample tests showed that

a) both the Hunter River plot and uncut control had significantly more insects per 10 leaves than the samples from Condura 73 and CUF 101 ($P < 0.01$).

b) within the Hunter River treatment samples the cut plot had significantly more insects per 10 leaves than the uncut control ($P < 0.01$).

c) there was no significant difference between or within the Condura 73 and CUF 101 treatment samples.

The insects collected were a mixture of species, the most abundant were Blue-green aphid and Spotted alfalfa aphid. The antibiosis of CUF 101 and Condura 73 towards these two species would account for the differences in insect numbers between these cultivars and Hunter River (Table 8). When CUF reaches the flowering stage the shoots in the basal crown start to grow, so that when the top growth is cut these shoots develop rapidly. In Hunter River and Condura development of the basal crown shoots does not seem to start until after cutting of the stems. The results of these varietal characteristics can be seen in cut plots in Table 8 with the CUF having stems about twice the length of Hunter River and Condura lucerne. Despite the extra growth in CUF there was no corresponding increase in insect numbers comparable with that in the Hunter River variety.

When large areas are cut and starting to recover the numbers of insects present when the crop is between 40 to 100 mm in height is usually very low, regardless of lucerne variety, whereas with the small plots the insects were able to recolonize the cut area rapidly from the surrounding tall vegetation.

5.5 DISCUSSION

Cutting of lucerne had devastating effects on the population of many insect species, (Figures 16, 18, 21). Some of this reduction may be due to the action of the cutting and harvesting machinery and to the emigration of insects. Lamont (1975) obtained similar results when a fire destroyed tropical grasslands. She suggested that the simplification of the habitat increased the chances of desiccation and made the searching by surviving predators and parasites easier; the same principles could apply to lucerne in the summer. Howell and Pienkowski (1971) observed that in their lucerne crops the numbers of some spider species were affected by harvesting while others were apparently unaffected. Southwood and van Emden (1967) compared cut and uncut grassland in England and found a greater density but slightly lower species richness of invertebrates in the cut grassland compared with the uncut area. Some species had benefited by the cutting but there was not the impact as in the Fyshwick situation, probably as a result of the wetter English climate. Other studies in England produce similar results (Morris and Lakhani 1979).

The sweep samples from Fyshwick in December 1979 show that the numbers of all entities were decreased by cutting but the reductions were not uniform. Adult Plague thrips (T2), larval *Heliothis punctigera* (S1A), apterous Blue-green aphids (L44A) were reduced by between 95 to 100 percent, whereas the apterous entity of the grasshopper *Phaulacridium vittatum* (A1A) and the predatory adult Lady beetle *Coccinella repanda* (C4) numbers declined by less than half. The disproportionally high numbers of plant-feeding insects in the tall crop are responsible for the low diversity values. Cutting and harvesting of the lucerne selectively destroys part of the insect population, affecting most the soft bodied plant-feeding forms. The situation illustrates the danger, highlighted by Cairns (1974) in trying to use diversity indices as a means of assessing the impact of disturbances on a community. Disturbances such as pollution or in this case, cutting of the vegetation, cause changes in the class composition whether species or entities. The impact of the disturbance may not be reflected in diversity values; for one group of classes maybe completely or partially replaced by another (Cairns 1974). When the impact has a selective affect and there is no replacement of numbers by other types, then diversity values can go up or down, depending on which group of classes is affected most. In the case of the lucerne insects, a normally low diversity type community responded to cutting with a temporary high diversity value, because the most abundant classes were disproportionately affected (Figure 21). The complete reverse of this situation can be envisaged where a normally higher diversity type community loses most from its middle ranking classes which would cause a sharp drop in diversity values.

Removal of weed foliage from small plots does not seem to have an effect on the numbers of insects. Stem sampling, showed that all the common plant-feeding species were associated with lucerne and related species. Non-legume feeding species like the aphids *Lipaphis erysimi* (Kaltenbach) *Hysteroneura setariae* (Thomas), *Hyperomyzus lactucae* (L.) were comparatively rare in sweep net samples.

The small cut plots experiments show that when newly cut lucerne is close to uncut plants the insects are able to rapidly recolonize the disturbed area. Bishop *et al.* (1980) found that lucerne that was cut and recovered had more Blue-green aphids than the adjacent uncut controls. When allowances are made for the differences in plant height the same trend appears to have occurred in the cut Hunter River plots at Ginninderra. The small number of stems left after mechanical harvesting probably play a major role in the recolonization of the crop after cutting. Improved machinery design which reduces the chances of leaving standing stems after cutting could be of considerable economic benefit to the grower in his attempts to combat lucerne aphids. The 40 mm of stubble which is left after efficient lucerne harvesting is not attractive to aphids.

6. THE VERTICAL DISTRIBUTION OF INSECTS ON LUCERNE FOLIAGE

6.1 INTRODUCTION

The typical cultivated lucerne plant is upright and smooth-leaved but there are also ground creeping and hairy leaved forms. Klages (1942) recognized five major types of lucerne. Variations in crop yield and plant longevity of lucerne cultivars, under different conditions have been intensively studied (Hely *et al.* 1977, Gramshaw *et al.* 1981, Farrell and Stufkens 1981, amongst others). Some of these studies deal with the patterns of lucerne growth, such as the plant stand density (Frakes *et al.* 1961) and variation in leaf dry weight per unit of leaf area (Barnes *et al.* 1969). However, the relationship between lucerne growth patterns and the distribution of insects seems to have received little attention (Walters, in Bishop and Holtkamp 1980), although plant growth form has been shown to be of importance in other plant based communities (Lawton 1978, Vickerman and Sunderland 1975, Murdoch *et al.* 1972, Strong and Levin 1979).

This chapter is concerned mainly with the three most common insect species found on lucerne: Blue-green aphid *Acyrthosiphon kondoi*, Spotted alfalfa aphid *Therioaphis trifolii* and Plague thrips *Thrips imaginis*. Assessment of the patterns of vertical distribution was made using various stem sampling techniques which because of the small amount of plant material examined, gave reliable data on only the most common insects.

6.2 METHODS

Plant measurements were made from stems which were cut at ground level and brought back to the laboratory. The stems were divided into 100 mm lengths of main stem and within each section the numbers of leaves, side branches, flowers, and nodes were counted. The standard sampling unit was thirty for leaves and stems at GES and Lake Ginninderra. Plant sampling was periodic and done in conjunction with the sampling of insects.

Leaflet axil lengths were measured during the autumn and spring of 1981. One leaflet was measured from each 100 mm section. The leaflet was the centre one of a leaf attached to a main stem node as near to the middle of the section as possible. If the leaf was missing, a leaflet towards the top of the section was selected.

In situ insect samples (Ch 2.5.2) were carried out weekly in the Hunter River lucerne at GES from 29 October 1980 to 10 May 1981 and also periodically on the adjacent Condura 73 and CUF 101 plots and at Lake Ginninderra this was discontinued when insect numbers became too low. Stem sections were, in terms of height from the ground, (1) 0 - 199 mm, (2) 200 - 399 mm, and (3) above 400 mm. The number of insects occupying the sites of under leaf, top of leaf, stem, and shoot were recorded for each stem section. The foliage was manipulated carefully with tweezers to avoid undue disturbance. Mobile insects were recorded as being on the site at which they were first observed.

A variation of the *in situ* sampling method was given limited use at GES. Half a metre of row was marked out with a measuring stick laid on the ground. The lucerne sample area was then searched rapidly and the numbers and placement of large mobile species like *Coccinella repanda* were recorded. Thirty such samples were taken at the time.

The insect cut stem samples (Ch. 2.52) were taken from late January to early March 1982. The plants were divided into 100 mm sections bringing this method more closely into line with the plant samples. The cut stem samples provided more accurate data on the numbers of small insects. Material was taken weekly from ten sample areas per plot. Each section sample consisted of 10 sections of stem which had been placed together in a plastic bag and returned to the laboratory for the removal and counting of insects.

A variation of the cut stem sampling method was employed to sample specific parts of the plant. Top terminal shoots, sections of main stem below the terminal shoots, flower and seed heads were sampled as above.

6.3 RESULTS

Measurement of these plant characteristics showed that there were no significant differences between the cultivars Hunter River, Condura 73 and CUF 101, except for those that could be related to the ability of CUF to recover more quickly after cutting (Chapter 5). In the spring of 1981 the Hunter River lucerne at Lake Ginninderra had significantly more side branches than the same variety at GES ($P < 0.05$) which probably resulted from the thinner plant stand at Lake Ginninderra.

In terms of lucerne foliage insects, leaf axil lengths (which are related to the size of leaves) and the vertical distribution of leaves and shoots are the most relevant characteristics. From late September to December 1981 30 lucerne stems were sampled weekly at Lake Ginninderra. The stems were cut at ground level and taken back to the laboratory where measurements were made. The Lake Ginninderra samples are discussed here because unlike GES lucerne which was sampled from September 1981 to April 1982, it was not subject to cutting. The Lake Ginninderra lucerne went through a complete cycle of development so that seeds were produced before the whole stems became senescent in late December.

FIGURE 22. Distribution of new leaves on lucerne stems. Lake Ginninderra. September to December 1981. Section 1 is from ground level.

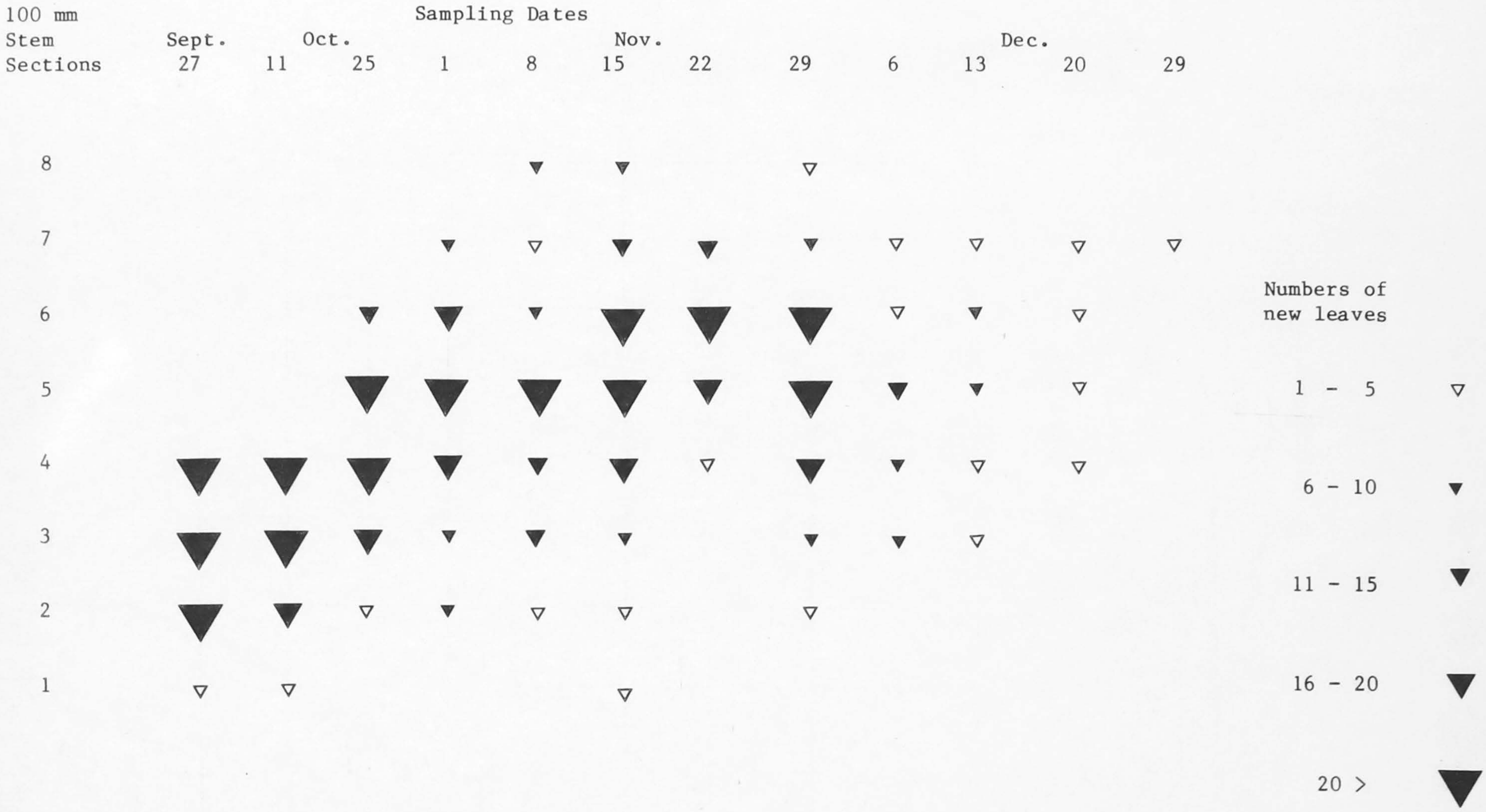

100 mm
Stem
Sections
Sampling Dates
Sept.
Oct.
Nov.
Dec.
27
11
25
1
8
15
22
29
6
13
20
29
8
7
6
5
4
3
2
1
Numbers of
new leaves
1 - 5
6 - 10
11 - 15
16 - 20
20 >

FIGURE 23. Distribution of mature leaves on lucerne stems. Lake Ginninderra. September to December 1981. Section 1 is from ground level.

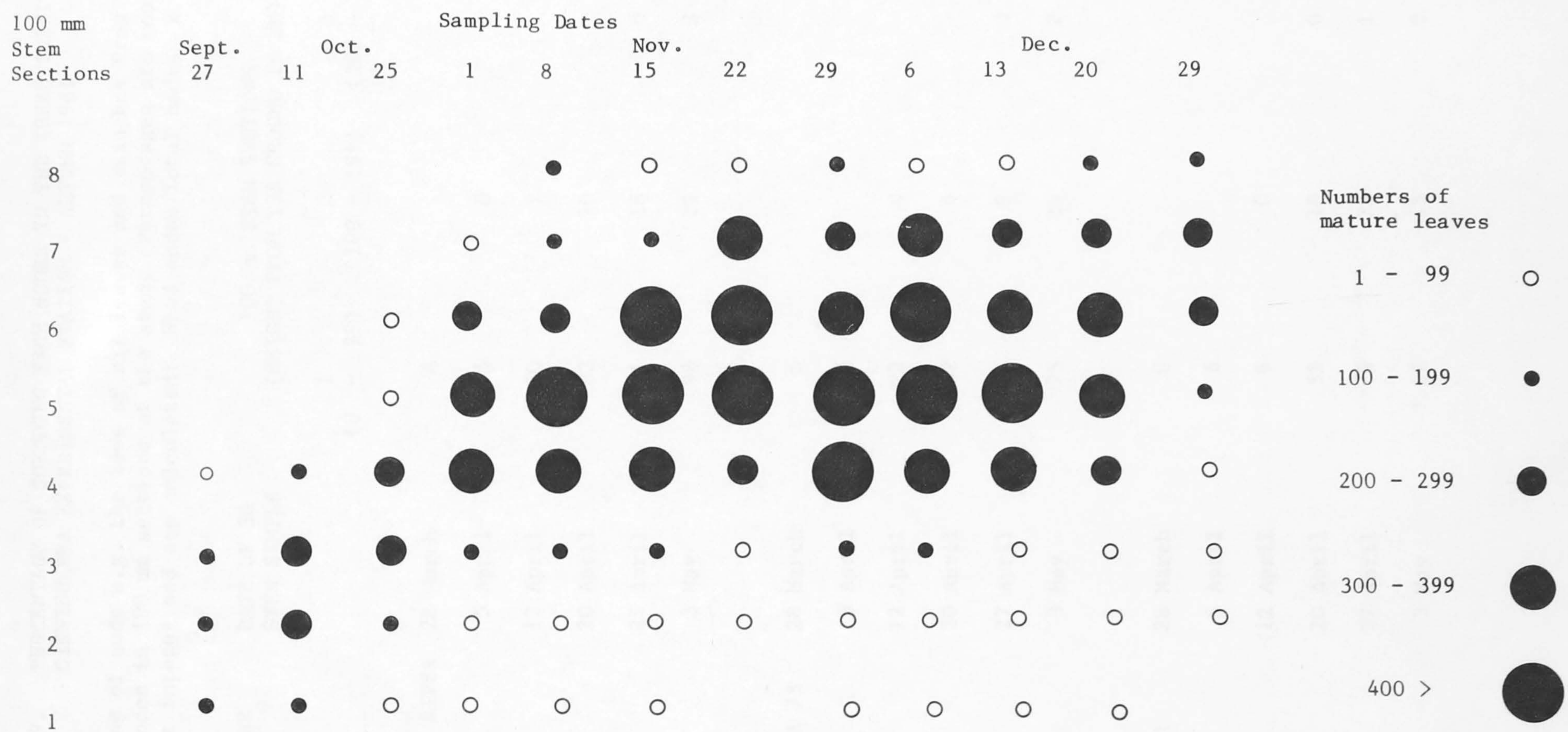

100 mm
Stem
Sections
Sampling Dates
Sept.
27
Oct.
11
25
Nov.
1
8
15
22
29
Dec.
6
13
20
29
8
7
6
5
4
3
2
1
Numbers of
mature leaves
1 - 99
100 - 199
200 - 299
300 - 399
400 >

TABLE 9. PERCENTAGE OF SHEDDING FROM NODES IN THE THREE CULTIVARS - GINNINDERRA EXPERIMENTAL STATION - AUTUMN 1981

Shedding of node e.g. the loss of all leaves and branches from the main stem nodes in 100 mm sections of the stem. Percentages are rounded to the nearest integer and are calculated: Shed nodes/Total nodes x 100%.

CULTIVAR	DATE OF 30 STEM SAMPLE	100 mm STEM SECTIONS (HEIGHT FROM THE GROUND IN MM)		
		1 (0 - 99)	2 (100 - 199)	3 (200 - 299)
HUNTER RIVER	28 March	6		
	5 April	5	0	
	12 April	70	2	
	20 April	82	10	
	27 April	91	18	0
	3 May	98	32	2
CONDURA 73	28 March	5		
	5 April	4		
	12 April	23	0	
	20 April	62	6	
	27 April	88	9	0
	3 May	75	14	2
CUF 101	28 March	0		
	5 April	6		
	12 April	6	0	
	20 April	55	18	0
	27 April	75	23	1
	3 May	66	15	0

TABLE 10. LEAF AXIL LENGTHS IN MM - GINNINDERRA EXPERIMENT STATION

Sections of main stem 100 mm in length.

Mean are of 30 leaflet samples in mm and standard deviations. Leaflets were taken as near to the middle of the section as possible if the leaf was missing a higher leaf was sampled. Section 1 is the section nearest to the ground.

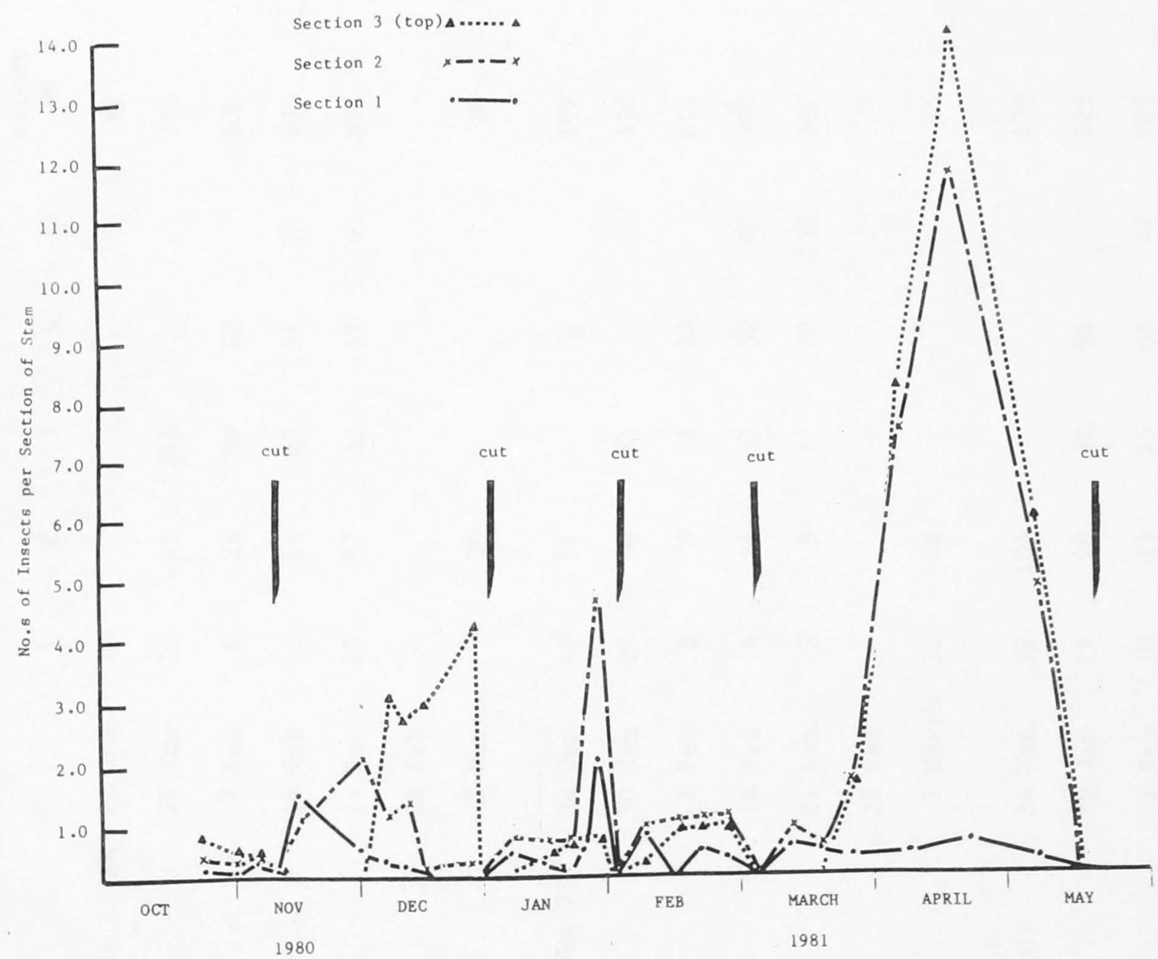
CULTIVAR	DATE	100 mm STEM SECTIONS 1	2	3	4
HUNTER RIVER	16 March	13.3 ± 2.70			
	22 March	14.9 ± 4.09	23.4 ± 3.97		
	28 March	15.4 ± 3.83	22.4 ± 2.88	25.8 ± 2.98	
	5 April	19.4 ± 5.28	24.2 ± 3.98	28.7 ± 3.67	29.7 ± 5.22
	12 April	-	21.7 ± 3.03	25.4 ± 3.90	28.1 ± 3.20
CONDURA 73	16 March	15.2 ± 3.45			
	22 March	17.2 ± 4.35	22.5 ± 2.68		
	28 March	16.5 ± 4.77	24.4 ± 4.24	28.9 ± 2.20	
	5 April	18.2 ± 4.61	24.8 ± 4.39	29.9 ± 4.27	
	12 April	21.0 ± 3.25	24.9 ± 5.03	27.6 ± 4.81	29.2 ± 2.49
CUF 101	16 March	13.4 ± 2.86			
	22 March	16.2 ± 4.63	22.5 ± 3.00		
	28 March	16.5 ± 5.45	23.3 ± 5.79	29.2 ± 5.27	
	5 April	16.9 ± 5.40	23.1 ± 5.88	29.1 ± 3.72	29.6 ± 3.82
	12 April	16.3 ± 4.15	23.8 ± 4.6	25.5 ± 3.60	24.6 ± 4.60

New leaves are those which have separated from the shoot but are light green in colour not having developed fully. Their number are probably the best guide to the presence of actively growing shoots (Figure 22). Shoots which develop on the lower parts of tall stems may remain inactive for long periods and are not particularly attractive to insects. Mature leaves are fully grown and have extended petioles. Senescent leaves were counted as mature. The system of vertical zonation was based on 100 mm lengths of main stem above the ground, so section 1 is from 0 - 99 mm, section 2 is 100 - 199 mm, etc, to section 8 at 700 - 799 mm.

The patterns of distribution of leaves at GES were similar to those at Lake Ginninderra with the greatest number of leaves occurring towards the top of the stem (Figure 23). The lake crop started to produce flowers about 8 November and under normal management, would have been cut about 15 November 1981.

The reduction in number of mature leaves from the lower sections was due to shedding (Figure 23). Table 9 shows the percentage of nodes per 100 mm section which had shed all leaves and side branches during the autumn of 1981, where crops at GES were cut in early March and again in early May. The cultivars at GES started to produce flowers in early April, so the lucerne was allowed to go about four weeks longer than may have been the case with commercial management before it was cut. The pattern of shedding shown in Table 9 was observed in other seasons. In the autumn of 1981, there was a tendency for leaflet size to increase progressively up the stem (Table 10). Student's t test showed that mean axil length for sections 2 and 3 were significantly greater than that for section 1 ($P < 0.01$) and that of section 3 was greater than that of section 2 ($P < 0.01$) in all three cultivars.

FIGURE 24. *In situ* stem samples Hunter River lucerne.
Ginninderra Experimental Station.
Insects per section of stem.



Section 3 (top)
Section 2
Section 1
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
No.s of Insects per Section of Stem
cut
cut
cut
cut
cut
OCT
NOV
DEC
JAN
FEB
MARCH
APRIL
MAY
1980
1981

TABLE 11. INSECT CUT STEM SAMPLES: NUMBER OF INSECTS (ALL SPECIES) IN EACH 100 mm SECTION, JANUARY - MARCH 1982

Ten samples were taken from each cultivar, per sampling day. There were 10 stems per sample. Sections from the ground were (1) 0-99 mm ..... (5) 400-499 mm. Mean plant height calculated from 30 stem samples. Sampling from 24 January to 7 March 1982.

CULTIVAR	DATE	100 MM SECTIONS					$\bar{x}$ PLANT HEIGHT
		1	2	3	4	5	MM
HUNTER RIVER	24 Jan	20					69
	30 Jan	21	48	218			172
	7 Feb	6	26	56	68		226
	14 Feb	3	16	27	54	70	265
	21 Feb	10	17	15	67	103	394
	28 Feb	-					-
	7 March	9	20				80
CONDURA 73	24 Jan	45	31				102
	30 Jan	26	54	81			130
	7 Feb	2	8	31	33		216
	14 Feb	4	14	37	52	40	301
	21 Feb	3	9	27	149	135	307
	28 Feb	-					-
	7 March	32	28				85
CUF 101	24 Jan	29	104				138
	30 Jan	17	28	72	94		229
	7 Feb	10	11	25	65	47	283
	14 Feb	10	12	28	156	219	297
	21 Feb	3	14	23	89	235	411
	28 Feb	4					38
	7 March	22	30	15			128

There were no significant differences for the equivalent sections between lucerne varieties. Axil length appears to relate to leaf size although specific measurements of leaf area were not made.

Figure 24 shows the vertical distribution of insects on Hunter River lucerne between incidences of crop cutting for the period October 1980 to May 1981. During November-December 1980 Plague thrips was the most commonly recorded species, in the autumn 1981 Blue-green aphid and Spotted alfalfa aphid became abundant, Figures 9, 10, 11 show the seasonal occurrence of these species as indicated by sweep samples.

The pattern of insect abundance is related to the growth of the plant, as the stems grow, the centre of insect population tends to move upwards to stay with the most actively developing part of the plant (Figure 24). The insect population increases rapidly which is reflected in the higher peaks of numbers in section 2 and 3. This pattern is best seen in the November-December 1980 period when Plague thrips were the most abundant species (Figure 24). Lucerne aphids, particularly Spotted alfalfa aphids feed on senescent leaves so that re-invasion of the section 1 may occur at a later stage.

Table 11 shows the total numbers of insects collected in each section by the cut stem method between 24 January and 7 March 1982 at GES. The three varietal plots were cut on 19 January and again on 23 February only CUF had recovered sufficiently by 28 February for samples to be taken. Plague thrips were the most common species in the samples. Wilcoxon two-sample tests of combined data for the 14 and 21 February when the crops were highest, showest that there was no significant differences between the total number of insects collected from the three cultivars. There were few aphids in these samples.

At the end of April 1982, the aphid population was again high and cut

TABLE 12. INSECT CUT STEM SAMPLES: NUMBER OF INSECTS (ALL SPECIES) IN EACH 100 mm SECTION, APRIL 1982

Samples as per table 11.

DATE	100 MM STEM SECTIONS					MEAN PLANT HEIGHT CM
	1	2	3	4	5	
18 April 82	14	20	41	55	65	48.5
24 April 82	23	66	107	103	150	42.4

TABLE 13. NUMBERS AND SITE DISTRIBUTION OF SPOTTED ALFALFA APHID AND BLUE-GREEN APHID IN HUNTER RIVER LUCERNE.

30 *in situ* stem samples.

SITES	SPOTTED ALFALFA APHID	BLUE-GREEN APHID	MEAN AND S D OF PLANT HEIGHT
	22 March 1981		
Shoots	3	0	12.6 ± 3.7
Upper side leaves	0	0	
Under side leaves	15	0	
Stems	0	0	
	12 April 1981		
Shoots	2	91	34.7 ± 6.1
Upper side leaves	28	6	
Under side leaves	173	25	
Stems	2	6	
	3 May 1981 (senescent lower leaves)		
Shoots	8	12	35.6 ± 7.2
Upper side leaves	24	12	
Under side leaves	253	72	
Stems	2	2	
	11 October 1981		
Shoots	0	333	39.4 ± 11.2
Upper side leaves	0	30	
Under side leaves	0	22	
Stems	0	9	

TABLE 14. PLAGUE THRIPS NUMBERS: CUT SAMPLES - GINNINDERRA EXPERIMENTAL STATION AND LAKE GINNINDERRA.

Total number of thrips removed from 10 samples from each lucerne cultivar.

GES = Ginninderra Experimental Station. LG = Lake Ginninderra.

22 November 1981.

CULTIVAR	MAIN STEM (4 NODES BELOW TOP TERMINAL SHOOT)	TOP TERMINAL SHOOT
Hunter River (GES)	100	68
Condura 73 (GES)	91	35
CUF 101 (GES)	84	47
Hunter River (LG)	98	54

stem samples were collected from the Hunter River lucerne. Most of the insects recorded in the April cut stem samples (Table 12) were either Blue-green aphid or Spotted alfalfa aphid. There was a niche separation between these two aphids, Spotted alfalfa aphid occurred most frequently on the underside of leaves while Blue-green aphid tended to occupy the shoots. However, with senescence of lower leaves in tall crops the Blue-green aphid found the leaf sites attractive. Table 13 shows the sites occupied by the two species as indicated by *in situ* sampling on four sampling days in Hunter River lucerne. By the beginning of May 1981 many of the lower leaves had become senescent and the top shoots damaged by frost.

Sampling of specific parts of the lucerne plant was designed to give a better understanding of the distribution of the smaller insects, the most numerous of which was the Plague thrips. On 22 November 1981 ten samples of 10 top terminal shoots were taken from the three varietal plots at GES and the Hunter River lucerne at Lake Ginninderra. Also collected were the same number of main stems sections which consisted of 4 nodes and accompanying leaves and side shoots from just below the top terminal shoots. Table 14 shows the total number of Plague thrips which were removed from the plant material in the laboratory. There was no significant difference between the numbers collected from the lucerne varieties or between 'Hunter River' at GES and Lake Ginninderra. It is not possible to compare the relative attractiveness of parts of the plant for Plague thrips with the data in Table 14. The same sampling methods were used with the GES plots on 31 January 1982. The Lake Ginninderra crop was no longer suitable. Again no significant difference was found between lucerne cultivars. Evidently the antibiosis which effects lucerne aphids on CUF and Condura does not extend to Plague

TABLE 15. NUMBERS OF PLAGUE THRIPS. LAKE GINNINDERRA LUCERNE - 15 NOVEMBER TO 22 DECEMBER 1981

Ten samples from each plant part per day.

DATES	TALL STEM FLOWERS HEADS	TALL STEM SEED HEADS	SHORT STEM FLOWER HEADS	ESTIMATION TOTAL THRIPS PER M^2
15 Nov	530	-	-	179
22 Nov	1082	-	-	1093
29 Nov	998	140	-	3462
6 Dec	924	60	-	2032
13 Dec	260	42	154	334
20 Dec	328	46	244	516

thrips but Bishop and Holtkamp (1980) found some reduction of *Heliothis* spp. numbers on CUF and Condura compared with Hunter River. No significant difference was found in the numbers of *Heliothis* larvae on these cultivars at GES (Appendix 1).

A similar series of cut samples of flower heads was taken from the Lake Ginninderra lucerne between mid-November and late December 1981 coinciding with the seasonal peak in Plague thrips numbers. When the lucerne started to produce flowers in early November the plants also sent up new shoots from the basal crown. This new growth started to flower while still only about half the height of the older stems.

Table 15 shows the numbers of thrips from the tall stems collected with ten samples of 10 flower and seed heads on each of the sampling days. The flowers of the short stems were sampled in the same way when they became available in mid December. The density of flower and seed heads were calculated and this was used to estimate the number of Plague thrips on flower and seed heads per m^2. This shows that the peak in thrips numbers occurred about the end of November. Student's t tests showed that there was no significant difference between the numbers of Plague thrips collected from the tall and short stem flower heads at the end of December but there was a significant drop in numbers between tall flower and seed heads, for all weeks $P < 0.01$.

The mirid *Campylomma livida* was the most common of the other species collected from lucerne flower heads but this and other species occurred too infrequently for analysis of their numbers. There was a much higher proportion of juvenile *C. livida* and Plague thrips from the flower samples compared with sweep and stem samples from lucerne not in flower.

Visual samples of half a metre of row at GES were made infrequently.

In the summers 1980-81 and 1981-82 the numbers of *Coccinella repanda* and *Dicranolaius bellulus* were closely related to the size of the aphid population. When the crop was tall they tended to spend most of their time in the upper parts of the foliage where most of their prey was located.

MacArthur *et al.* (1962) showed that species diversity (H) of forest birds was correlated with structural diversity of the habitat and Murdoch *et al.* (1972) found a similar relationship with insects in abandoned fields which supported various types of regenerated vegetation. Structural diversity of lucerne can be calculated from the distribution of leaves. Leaf diversity (where n_i is the number of leaves in the ith 100 mm section of a 30 stem sample and N is the total number of leaves in the sample) was found to correlate with crop height ($P < 0.01$). MacArthur *et al.* (1962) and Murdoch *et al.* (1972) calculated structural diversity on estimates of vegetation density at different levels, so the methods are comparable with those used for lucerne. The entity diversity of lucerne insect populations declines while plant structural diversity increases and there was no correlation between them even though entity richness and total insect numbers also increase (Figures 18, 19, 20).

6.4 DISCUSSION

In Chapter 5 it was shown that there was a correlation between the numbers of insects collected by sweep sampling and crop height. This is also demonstrated here with the stem samples (Table 11). Both types of insect stem samples (Figure 24 and Table 11) show that the insects change their vertical distribution as the crop develops, so that upper parts of the lucerne stem accommodate the increasing population while there is usually a net loss from the lower sections. These distribution changes on insects are closely correlated with the distribution and changes in the sizes of leaves (Figure 23, Table 10), also the degree of shedding of foliage in the lower sections, factors that make the upper part of the stems more attractive when the plant is tall. Lucerne aphids find the senescent leaves in the lower sections of tall stems attractive but there does not seem to be any common species which is specifically associated with this type of foliage. Possibly this niche is too transient.

Flowers appear at the top of the stem first at the nodes just below the top terminal shoot. Then the terminal shoot produces flowers and then the nodes, going progressively down the stem to about a third of its length. Cutting usually takes place about a week after the first flowers appear in Hunter River lucerne, somewhat later in CUF 101 and Condura 73, so that there is normally little chance for insects to fully exploit the niche presented by lucerne flowers.

Observations of the unmanaged lucerne at Lake Ginninderra showed that if the crop is not cut at the flowering stage as is usual, seed will set and the shedding of the foliage will progress upwards so that the habitat will become increasingly unattractive to most insects. The extent of shooting from the basal crown varies with soil moisture. At Lake Ginninderra in late 1981 these secondary stems were less well developed and produced fewer flowers. The stand density of primary and secondary stems was estimated at 67 and 25 per m^2 respectively. All these factors indicate that the habitat was deteriorating for lucerne insects from mid November onwards. Even if there had been an increase in soil moisture in November much of the plant energy would have gone into producing seed rather than foliage. Observations at

Lake Ginninderra in previous summers suggest that the lucerne responded vigorously to summer rain only after the senescent growth from the preceding spring had been removed.

Foliage only represents part of the crop profile, the soil and the litter layer were not sampled and would have supported quite a different type of arthropod fauna (Nyffeler 1982, Room 1975, Vickerman and Sunderland 1975). Insects such as *Dicranolaius bellulus* were only recorded as adults, the larval forms were associated with litter and soil.

The absence of correlation between insect and leaf diversity of lucerne seems completely at variance with the results of Murdoch *et al.* (1972) but they did not include aphids in their analysis which may have made a difference to the results.

7. GENERAL DISCUSSION

Pimentel and Wheeler's (1973) study on insect communities in lucerne has tended to highlight the problems of studying crop insects. In the present study, the method of using entities and excluding most rarities from the analyses seems to have gone much of the way to solving these problems. There is little information on crop-based insect communities and it is hoped that these methods can be used elsewhere. The practice of excluding juveniles from much of the analysis seems suspect, for it appears that in some studies particular periods have been chosen for sampling because there was known to be a seasonal low in the numbers of juveniles (Janzen and Schoener 1968, Murdoch *et al.* 1972). In some species the proportion of larvae to adults can be substantial; in *Heliothis punctigera* the proportion is often about 100 to 1 and sometimes it is much higher. Large juvenile to adult ratios can be expected in species with high juvenile mortality. The elimination of rarities from the analysis except where they are needed to calculate richness, seems to be less drastic as they only form a small proportion of the total.

Indices enable large amounts of class data to be summarized into single variables but it is possible that some of the methods in vogue will be shown to be misleading in the light of further studies (Peet 1975). It is a mistake to regard the class data as bits of information without considering the roles of the entities or species (Dritschilo and Erwin 1982). The fluctuations of the Simpson-Yule (D) and Shannon-Weaver (H) diversity values for the insect community at Fyshwick during a sequence of cutting and regrowth could have been completely misinterpreted if it were not realized that many of the changes were due to the vulnerability of the phytophagous insects to crop cutting. Calculations using seasonal species-entities data from GES showed that diversity D was negatively correlated with total numbers (Figure 8) for all three cultivars. This is the same pattern as seen over a shorter period and a cutting sequence at Fyshwick (Figures 18, 20).

The extreme fluctuations in the populations of plant-feeding insects, gives the lucerne community its character. This may be a feature of most insect communities, so caution is required in attempts to link insect communities with general theories developed for vertebrates (MacArthur 1975). It was perhaps the failure to appreciate these differences which lead to the demise of the diversity stability theory (Goodman 1975). This theory was developed for crop systems in the 1950's and 60's (Watt 1965, Pimentel 1961a, Way 1966), though some of the observations which lead to the development of the theory were much older (Graham 1926, von Hassel 1925, Friederichs 1928, Marchal 1908). MacArthur (1955) suggested that stability was related to the number of species links in the community which provide paths for energy flow. It was proposed that increasing the plant species diversity, and through this the diversity of the insect community, would dampen down the perturbations of insect pest populations. It was suggested that perturbation of animal and insect populations tended to be greater and more frequent in comparatively simple communities such as in the Arctic, when compared with complex communities found in parts of the tropics (Hutchinson 1959). Pimentel (1961a) provided some experimental evidence to support the theory with his work on *Brassica oleracea* cultivars and their associated insects but as van Emden and Williams (1974) observed;

"We can not expect to mimic the evolutionary diversity of mature natural systems in agro-ecosystems which have entirely different characteristics."

The characteristics which set agricultural systems apart are: -

1) The diverse origins of the species which make up the community and their lack of co-evolution.

2) The genetic divergence of many agricultural plants from the ancestral stock which has left some cultivars particularly vulnerable to insect attacks.

3) For economic reasons most crop plants are best managed as monocultures.

All these characteristics are found in the Australian lucerne crop. The diverse origins of the insect species means that the degree of sophistication in the proportioning of available resources is rather low. It contrasts strongly with the high degree of niche separation and consequent efficient energy flow in mature communities (MacArthur 1955). The appearance of "new species" in the crop systems causes disruption, rather than stability. This is well illustrated by the outbreaks of lucerne aphids which have sometimes been so devastating that whole lucerne crops have been destroyed (Dickson *et al.* 1955). Although there were predators in the lucerne habitat which were able to attack the aphids when they appeared, they were incapable of having any substantial affect on the new species.

A further indicator of the immaturity of the lucerne community is the apparent lack of diurnal changes in the species collected from the foliage in the day and night sampling at Fyshwick. One might have expected that there would be a group of species which shelter in the soil and litter in the day and occupy the foliage at night. The only evidence of this was in the frequency of collection of White fringed weevil. The absence of such a group of species suggests that there are unfilled niches in the lucerne system.

There apears to be some seasonal niche separation between Blue-green aphid and Spotted alfalfa aphid (Figure 9, 10) and in feeding site preferences (Table 13) as also occurs with other species of aphids (Bradley 1959, Ito 1955, Addicott 1978, Tamaki and Allen 1969). However the niche separation in lucerne aphids may be due to factors other than competition. Spotted alfalfa aphid is prevalent in the warmer months and the tendancy to occupy the underside of leaves results in the centre of populations being lower in the crop profile and therefore better able to withstand desiccating conditons. Blue-green aphid is prevalent in the cooler months, although a small population is present in lucerne throughout the summer. Its favoured feeding sites are lucerne shoots so the centre of population is higher in the crop profile at a time when desiccation is not usually a hazard. If these two species of aphid evolved in geographical isolation then any niche separation is likely to be coincidental. The occupation of senescent leaves by both species in autumn (Table 13) suggests that inter-species competition for feeding space is not substantial. Limited data on Pea aphid *A. pisum* indicates that they tend to be more evenly distributed between shoots and leaves and therefore occupy the niches of both Blue-green aphid and Spotted alfalfa aphid.

The apparent lack of appropriate studies of the lucerne insect community before the arrival of the lucerne aphids in 1977, means that there is uncertainty concerning the pre-aphid community. It is possible that the seasonal trends in numbers were similar to those shown for the NLAT group (Figure 12) but the presence of Spotted alfalfa aphid and Blue-green aphid, even when they are not abundant, is likely to influence many aspects of the lucerne community. Probably these two invading species moved into a previously unoccupied niche in the lucerne crop which could account for their devastating and rapid spread in Australia. Although there are other leaf feeding and plant-sucking insects, the only species which has a role similar to that of lucerne aphids is the Cow pea aphid *Aphis craccivora* which is able to survive on Hunter River lucerne but is more commonly found on other legumes.

The appearance of lucerne aphids in Australia has probably been of benefit to several predatory insects although lucerne crops were subject to regular insecticide treatment where previously chemical sprays had been used infrequently. Comparison of sweep samples from 1980-82 of the untreated plots at Ginninderra Experimental Station showed that at least two aphid predators *Coccinella repanda* and *Micromus tasmanae* and possibly others had significantly larger populations on Hunter River compared with the aphid resistant CUF 101 lucerne. If the oscillations of a simple predator-prey model (Odum 1971) (where there is a peak in number of the prey followed by a peak in predators) are expressed as ratios, the pattern is similar to that of Figures 13, 14, for the periods winter to mid-summer 1980-81 and 1981-82. In this model the numbers of prey are significantly reduced as the predator population reaches its peak. The presence of lucerne aphids can increase the numbers of predators in early spring when other prey species are scarce but the decrease in Blue-green aphid numbers in late October apparently related to a seasonal increase in temperature, rather than a substantial increase in predation. Prior to the decrease the ratio of aphids to aphid predators may be several hundred to one (Figure 14). The decline in aphid numbers is rapid, taking less than a week and is not related to predation. If the aphid numbers are low in summer the predators may attack other prey and so the whole character of the community is altered.

Some of the fungal pathogens which affect lucerne aphids were present in Australia before 1977, others have since been introduced (Milner 1978, Milner *et al.* 1982). The pathogens which attack lucerne aphids are host specific or have a range confined to other aphid species (Cameron and Milner 1981, Milner *et al.* 1980). The fungal diseases, are unlikely to attack other common lucerne insects. A similar situation exists with introduced aphid parasitoids such as *Trioxis complanatus* Quilis which has become the most widespread and effective of the insects introduced to control lucerne aphids (Woolcock 1978, Hughes pers. comm.). The effect of this introduced species on common lucerne insects other than its host Spotted alfalfa aphid, should be negligible, except when it suppresses an already small aphid population, in which case the parasitoid could have an indirect effect on aphid predators through the reduction of prey numbers. Most parasitoids have a narrow host range (Varley *et al.* 1973) and when introduced into a new region they are not likely to cause the sort of disruption that can occur with some predators (Taylor 1937).

Despite the appearance of Pea aphid *Acyrthosiphon pisum* in 1979 the numbers of lucerne aphids has declined in south eastern Australia. This is probably due to the impact of introduced parasitoids, pathogens and resistant varieties of lucerne, the adjustment in the behaviour of predatory insects and progressively dryer conditions with the onset of a major drought. Hunter River Lucerne is destined to be replaced by newer varieties, and the situation in which one cultivar is grown throughout Australia is never likely to arise again. The appearance of the exotic aphids and all the ramifications discussed above suggest that the lucerne insect community has passed through a revolutionary change since the mid 1970's. The antibiosis in the introduced lucerne cultivars inhibits lucerne aphids (Figures 9, 10, 12) but as with chemical pesticide the affected insect species can become resistant, so that the lucerne industry may again be faced with serious aphid problems. A strategy of reliance on aphid-tolerant, rather than highly resistant cultivars may prove to be the better choice for the selective pressures on the aphids are less likely to produce resistant strains (Nielson and Lehman 1980).

Roberts (1969) said of some pest species:

"If Man is creating many of his pest problems through modification of the environment it follows that he should be able to solve at least a good share of them by counter-modifications or adjustments to agricultural practice."

In this study it became apparent that the situation for insects was different between the dryland and irrigated lucerne (Figure 4, 5, 6). This warrants a more complete study. Insect pests are far less of a problem on dryland lucerne even though the seasonal trends of numbers are similar to those of irrigated lucerne. Frequent cutting and watering of lucerne seems to create conditions which are more favourable to insect pests. A comparison of the feeding sites for herbivorous insects on the plants showed that there was no difference between irrigated and dryland lucerne. This contrasted with observations of Blue-green aphid and Spotted alfalfa aphid under glasshouse conditions, where the stems were much more attractive than with field grown lucerne.

Cutting and irrigation may make the lucerne more palatable but this is a supposition which needs further investigation. The tendency for aphids to find stems more attractive when the lucerne is grown in the glasshouse suggests that the indoor plants may have thinner cuticles but the differences between irrigated and dryland lucerne might be biochemical. The slower growing stems of the dryland lucerne could have higher levels of insect toxins. A third type of defence of plants against herbivores is lowering the levels of usable nutrients (Wolda 1978, Coley 1980) but this is not likely to be found in a fodder crop plant, as breeding presumably tends to produce cultivars which are nutritious to domestic stock and therefore to insects. The increase in the numbers of lucerne aphids on senescent leaves before they are shed by the plant results from a deterioration of the defensive systems within the leaf. Observations at Lake Ginninderra show that without cutting or grazing the condition of the lucerne deteriorates for most insect species, due to loss of leaves. The relationship between plant architecture and insects has been reviewed by Lawton (1983). The process in lucerne which is being cut or grazed is similar to that in other herbaceous plants which build up their architecture each season but in cultivated lucerne these processes occur with a higher frequency. The general trend from other studies shows a correlation for numbers and species richness with increasing plant structural complexity, a pattern which is similar to that occurring in lucerne crops. My results, when compared with those of Murdoch *et al.* (1972) with regards to diversity suggest that much more needs to be done before any general theories can be put forward. In lucerne insect diversity tends to be negatively correlated with increasing plant structural complexity, the result of a disproportional increase in the relative numbers of some phytophagous species. This is a pattern not evident in the plant-insect communities discussed by Lawton (1983) but one which could occur in other crop systems. The results from the small plot cutting experiments (Table 7, 8) show that short but rapidly growing lucerne stems are highly attractive to insects. The normally low numbers of insects which occur at this stage of crop development (Figure 18) are due to the reduction in the size of the insect population by extensive devastation of the habitat by cutting.

Experimental removal of weed foliage within small plots at Fyshwick showed that there was no subsequent effect on the insects collected by suction sample (Table 6). Speight and Lawton (1976) demonstrated that density of weeds in cereal crops was correlated with the numbers of ground beetles. In the light of these findings the value of complete removal of weeds from lucerne by herbicides needs to be examined.

Another aspect which needs fuller investigation is the pressure of grazing by cattle and sheep on the insect community. Grazing by cattle was observed infrequently at Fyshwick but there was no opportunity to study grazing by of sheep in isolation. Sheep tended to crop nearer the ground than cattle which may have implications for the survival of some insect species, particularly as any short pieces of leafy stem in stubble will be a refuge for insects. An answer to the problem of the occasional lucerne stems being left by mechanical harvesting may be to put sheep on the irrigated lucerne stubble. The benefits to this approach may be offset by the damage that such grazing might do to the plant; for unlike dryland lucerne subject to regular grazing by sheep, irrigated lucerne which is cut for hay, develops basal crowns above ground.

Insect community studies may provide valuable information on the full effects of modifications in farming practices. The wider application, the management of whole communities is a logical step from the purely monitoring process. The failure of the diversity-stability theory to make any impression on farming practices is due in part to the development of the concept through the study of non-agricultural communities. An aspect of the matching of theory with practice which is sometimes overlooked is the importance of economic threshold (Thompson 1956). Irrigated crops always have lower economic thresholds than dryland situations because production must cover the cost of water (Headley 1972). Even if the ecology of irrigated and dryland lucerne were similar, strategies for manipulation of the communities may have to be dissimilar for economic reasons. The studies on lucerne in the Australian Capital Territory show that much more needs to be known about crop-based communities before any theory can be put to practical use.

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APPENDIX 1. Seasonal Fluctuations of Numbers of the Most Common Species per Sweep Sample, Ginninderra Experimental Station.

Also see Figures 8, 9, 10 and 11.

H = Hunter River Lucerne

D = Condura 73 Lucerne

F = CUF 101 Lucerne

Some of this data was compiled from sweep samples made by the Aphid Biological Control Section, CSIRO Division of Entomology.

Species	Cultivar	Autumn 1980	Winter 1980	Spring 1980	Early Summer 1980	Mid Summer 1981	Late Summer 1981	Autumn 1981	Winter 1981	Spring 1981	Early Summer 1981	Mid Summer 1982	Late Summer 1982	Autumn 19..
Coccinella repanda	H	4.2	0.1	2.8	4.7	15.9	3.2	0.6	0.5	0.6	2.4	1.0	0.6	1.5
	D	1.4	0	2.7	1.7	3.1	0.4	0.4	0.2	0.4	2.9	1.8	0.5	0.6
	F	1.0	0	1.2	0.9	2.9	0.7	0.1	0.5	0.3	2.1	0.8	1.4	0.5
Diomus notescens	H	0.3	0	0.4	1.3	8.8	1.3	0.1	0.1	0.2	0.9	0.4	0.6	0
	D	0	0	0.4	0.1	10.2	0	0.1	0	0.4	1.1	1.8	0.3	0
	F	0.1	0	0.1	0	0.4	0.1	0	0.2	0.3	0.6	0.8	0.4	0
Sitona humeralis	H	9.3	0.4	2.4	0	0.3	0.9	5.9	1.1	1.9	3.4	0.7	0	15.3
	D	9.7	0.5	2.2	0	0.2	1.4	3.7	0.4	2.3	2.5	0.1	0.1	14.0
	F	6.8	0.7	3.7	0	0.3	0.8	3.6	1.6	2.1	1.6	0.1	0	5.8
Dicranolaius bellulus	H	1.7	0	0	0.9	6.3	1.5	0.8	0	0	0.6	0.4	0.5	0.2
	D	1.0	0	0.1	0.6	3.2	0.6	0.9	0	0	0	0.6	0.5	0.1
	F	0.4	0	0.1	0.7	3.1	1.3	0.6	0	0	0.1	1.2	0.8	0.5
Nysius vinitor	H	0	0	2.9	5.9	2.7	0.1	0.5	0.1	2.8	8.5	0.6	1.0	0
	D	0.2	0.1	1.8	5.4	2.6	0.2	0.3	0.1	3.5	6.4	1.5	1.1	0.1
	F	0.2	0	1.8	4.7	1.5	0.2	0.1	0.1	2.1	4.6	2.4	0.4	0
Campylomma livida	H	0.5	0.1	11.7	12.2	40.9	11.3	2.4	0	28.9	9.4	4.6	3.1	0
	D	0.2	0	18.4	6.4	16.7	2.4	1.3	0	18.7	7.6	15.7	4.3	0
	F	0.1	0	22.3	14.5	23.2	6.5	1.1	0	21.9	10.0	23.3	6.3	0.1
Creontiades dilutus	H	5.8	0	0.5	5.7	14.6	5.5	3.2	0	0.1	2.1	6.5	4.9	5.2
	D	1.5	0	0.2	4.0	12.1	2.5	2.5	0	0.3	0.8	5.2	6.9	2.4
	F	4.4	0.1	0.7	4.2	13.9	2.5	2.8	0	0.2	2.6	8.5	4.6	4.4

Species	Cultivar	Autumn 1980	Winter 1980	Spring 1980	Early Summer 1980	Mid Summer 1981	Late Summer 1981	Autumn 1981	Winter 1981	Spring 1981	Early Summer 1981	Mid Summer 1982	Late Summer 1982	Autumn 198
Acyrthosiphon pisum	H	0	1.4	9.7	26.2	8.5	5.6	113.1	0.5	7.5	2.4	1.4	0.7	7.0
	D	0	0.2	21.9	2.2	1.4	2.1	63.4	0.3	3.3	0.5	0.1	0.6	0.6
	F	0	0.4	9.4	0.9	0.4	0.5	16.8	0.1	1.0	0.4	0	0.1	0.7
Katianna australis	H	0	1.2	0.3	0	0	0	0.1	37.1	0.1	0	0	0	0.5
	D	0	0.9	0.2	0	0	0	0	55.2	0.2	0	0	0	0.6
	F	0	0.4	0	0	0	0	0.1	57.1	0	0	0	0	0.1
Simosyrphus grandicornis	H	0	0	12.0	0.9	0.4	0.1	0.5	0	2.5	0	0	0	0.1
	D	0	0	10.4	0.3	0	0	0.2	0	2.5	0.7	0.1	0	0
	F	0	0	9.0	0.1	0	0	0.1	0	1.5	0	0	0	0.1
Heliothis punctigera (larvae)	H	0	0.1	22.4	2.2	0.1	0.9	0.3	0	26.7	5.0	1.0	0.5	0.1
	D	0	0	23.6	1.2	0	1.0	0.7	0	23.8	6.4	0.7	0.6	0.1
	F	0	0	28.9	1.8	0.2	0.7	0.9	0	21.3	6.0	1.4	0.8	0.1
Micromus tasmaniae	H	0.5	0.3	7.0	1.7	1.7	2.7	1.0	0.1	3.1	0.7	0.1	0.2	0.1
	D	0.1	0.1	4.2	0.6	0.2	0.1	0.8	0.1	3.0	0.7	0	0.2	0
	F	0.1	4.3	2.6	0	0.1	0.1	0.6	0.8	3.8	0	0	0	0.1